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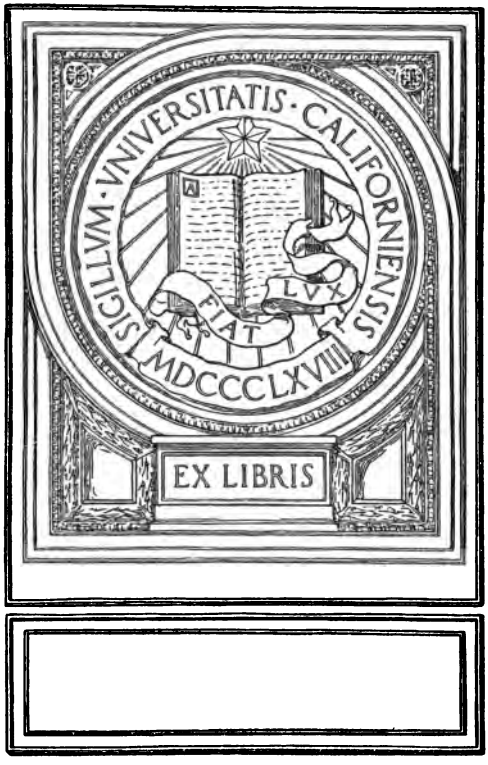

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UNITED STATES RAILROAD ADMINISTRATION

DIRECTOR GENERAL OF RAILROADS

DIVISION OF OPERATION—MECHANICAL DEPARTMENT

Report of a Subcommittee of the Committee on Standards

on the

Flexible Fire Box and Tube Plate Construction Proposed by the William H. Wood Locomotive Fire Box and Tube Plate Company

UNIV. OF CALIFORNIA

Approved by the
Committee on Standards
at
Washington, December 3, 1918

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REPORT OF COMMITTEE.

PHILADELPHIA, *November 12, 1918.*

MR. FRANK MCMANAMY,
Assistant Director, Division of Operation,
Chairman, Committee on Standards for Locomotives and Cars,
United States Railroad Administration,
Washington, D. C.

DEAR SIR: Your committee, to whom was assigned the question of the use by the United States Railroad Administration of the corrugated locomotive fire box invented and patented by Mr. William H. Wood, of Media, Pa., submits the following report:

The Wood fire box, so far as we can learn, has been tried in five locomotives, viz, three 2–8–0 type on the New York Central, one 10-wheel type on the Atlantic Coast Line, and one Atlantic type on the Union Pacific.

All of these boxes have been withdrawn because of defects after a comparatively short life.

Other Wood fire boxes have been designed or constructed but not put into use.

Of the many claims made by the inventor, the following seem the most important:

1. Flexible construction so that the box can freely expand and contract without injury to itself.
2. Great reduction in the number of stay bolts and consequent reduction in the number of bolts broken.
3. A construction very much stronger than the standard one (stated to be eight times as strong).
4. Economy in fuel due to increased fire-box heating surface.
5. General reduction in cost of maintenance.

CONSTRUCTION.

The construction is in general the same in all of the applications made by Mr. Wood, viz: The corrugations run from a little above the mud ring on one side clear around to the mud ring on the other side. The stay bolts in the corrugated surfaces are on the bends of the corrugations next to the fire, so that the ends of the stay and crown bolts are exposed to the fiercest blast of the fire. The reduction in the number of stay bolts is effected by increasing the spacing between the bolts to from 5 to 5½ inches, as compared with the usual distance of about 4 inches. This means an increased area supported by each bolt, and bearing in mind that the outer wrapper

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sheets are in all cases flat plates of the usual form, it is difficult to see how the claims for increased strength are to be maintained.

The back sheets of the fire boxes are in all cases flat stayed surfaces of the usual form. The tube plates, both front and back, differ from the usual form in having a deep corrugation running entirely around the group of tubes, the corrugation in the front sheet being quite close to the inside of the shell. These corrugations are away from the fire and their purpose is to provide for any necessary expansion or breathing of the tube sheet. The throat sheet and that part of the tube sheet below the corrugation is of the ordinary form.

In the New York Central boxes the dimension of the tube sheet over the flanges is greater than the dimension across the corrugations in the side and crown, so that to replace the tube sheet it would have to be dropped down, a difficult operation even if possible at all, concerning which possibility there is difference of opinion.

In the appendix will be found (letter Oct. 7, 1918) a discussion by Mr. Purcell of the construction of the Wood fire box, in which in general the committee concurs.

WOOD FIRE BOX ON THE NEW YORK CENTRAL.

Three consolidation locomotives on the New York Central were equipped with the Wood fire box:

No.	Applied.	Withdrawn.	Mileage.
			Miles.
2481	Mar. 6, 1909	Dec. 7, 1912	132,305
2490	Dec. 5, 1908	Aug. 24, 1912	131,666
2494	Jan. 9, 1909	Aug. 10, 1912	114,060

All of these boilers are still in existence at Depew shops. Although the sheets are more or less rusty, they bear plain evidence of persistent leakage around the stay bolts, and still more so around the button head crown bolts. The cracks seem to be more in the horizontal direction than in the vertical. The fire ends of the stay bolts appear to have been frequently calked. The corrugation around the tube sheet is in each boiler badly cracked from the water side, and in one case is plugged with copper. While not in a dangerous condition, the boilers are certainly unfit for service.

Unfortunately the early part of the life history of these boilers was lost in a fire at the office where it was on file, but the data which is available, dating to October, 1910, shows that at that time cracking around the tube sheet, at the arch tube holes and around the stay and crown bolts, was becoming quite frequent. The accumulation of scale around the crown and radial stays was also giving trouble, the position of the stay bolts interfering with the proper washing.

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While the locomotives were still running, and about a year before they were withdrawn, two of the three, viz, Nos. 2481 and 2494, were examined and reported upon by the chief stay bolt inspector of the Pennsylvania Railroad at Buffalo, who noted the cracking around the tube sheet and the leakage at the bolts.

Photographs of the water side of the tube sheet show how badly the corrugation around it had cracked.

The only point upon which these boilers showed any superiority was in the number of broken stay bolts, but it is to be noted that the total life did not extend to the period when heavy breakage would ordinarily be expected.

WOOD FIRE BOX ON THE UNION PACIFIC.

The Wood fire box was applied to one Atlantic type locomotive, No. 20, April 14, 1910, and removed May 1, 1912.

A careful personal inspection was made by Mr. Purcell and a representative of Mr. Bentley. These reports are appended. The gist of them is to the effect that the crown and side sheets have a total of 202 cracks, of which 51 are plugged. The corrugation around the tube sheet has acted very much as it did in the New York Central locomotives. These reports are in general in line with that submitted by Mr. Bentley, which is also appended. The Union Pacific records show that a leakage around bolts began within six weeks after the engine with the Wood fire box was put into service, and these leakage reports continued during the life of the box. Cracking was not reported until the box had been in service eight months, after which the number reported rapidly increased.

A noticeable feature of the behavior of the tube sheet was the development of a secondary corrugation running around below the original one.

The total mileage of the fire box was 135,958 miles. The average of engines with the same water conditions, during the same period, was 224,331 miles.

In the case of both the Union Pacific and the New York Central locomotives the water conditions were bad, but no worse for the Wood fire box than for the standard design.

WOOD FIRE BOX ON THE ATLANTIC COAST LINE.

Atlantic Coast Line locomotive No. 1019, equipped with the Wood fire box, was placed in service September, 1912. The first cracking in the fire box was reported in April, 1915, and the box was removed from the locomotive in December, 1916.

The history of the development and location of the cracking and of the continual leaking is very much the same as that of the others already reported.

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The life was but four years and three months in a good water territory, where the ordinary life is from 10 to 12 years. If the Wood box is to give satisfaction anywhere, it should have done so on the Atlantic Coast Line, where the water conditions are excellent, probably inferior only to the same conditions in the New England States.

OTHER DATA.

Your committee submits print showing back head of locomotive of the Lancashire and Yorkshire Railway, England, whose locomotive superintendent, Mr. George Hughes, advises that this form was extensively used to facilitate the application of fire boxes, but that the cracking became so bad in corrugation they were obliged to replace it with the ordinary back head.

Everything goes to indicate that a corrugation of this kind in a large sheet takes the bulk of the breathing, to its own destruction. In the case of the back-flue sheet the working of the flues always tends to stretch the sheet, frequently causing bulging. In the Wood box this bulging is relieved by the bending of the corrugation, which probably explains the large cracks on the water side of the bend.

It may be asked why this design of fire box has performed so badly in locomotives, while the corrugated box is in general use in marine boilers of the Scotch type the world over. The probable reasons are that the marine furnace is truly circular and the corrugation is principally to stiffen the box against external pressure, in order that furnace stay bolts may be entirely omitted. It is also to be remembered that in marine practice the rate of combustion is much slower than in the case of locomotives, and the feed water is condensed, the main impurity being due to condenser leakage.

ECONOMY.

The claims to economy are not founded on any extended data. The only data that your committee has seen is that from two round trips with one of the New York Central locomotives equipped with the Wood box, compared with two round trips with a locomotive of the same type equipped with the plain fire box. The westbound trips show in favor of the corrugated fire box; the east bound ones show in favor of the locomotive with the plain box. The tonnage loading is eastbound, the westbound being to get power in place.

It is extremely unwise to base conclusions on such limited data, especially from a road test where so many variables affect the final result.

There is no reason to expect any measurable difference in the evaporative performances of the two types of box beyond that due to actual difference in the heating surfaces. Mere change of shape does not, so far as we can learn, have any bearing on the efficiency

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of a given heating surface, and the increase in area due to the corrugated as compared with the plain surface is too small to be considered. On the other hand, the leakage that has appeared with every one of the Wood boxes is a direct source of loss, enough, in our judgment, to offset any increase in economy due to construction.

SAFETY.

On the score of safety your committee has no evidence based on the service of these fire boxes. Fire-box failures are practically all due to neglect in operation or maintenance, and in the vast majority of cases are due to low water. It does not appear that any of these boilers have been subject to low water, and the lives were entirely too short to reach the stage where neglect in maintenance would be the cause of failure. In most cases of failure by low water the failure is partial, the overheated sheets pulling from the crown stays, usually with resulting drop of the crown sheet and frequently distortion of the roof sheet, the discharge of the contents of the boiler through the opening relieving the pressure and dampening the fire. In the absence of direct evidence it seems futile to speculate as to just what would happen with the Wood fire box in the case of low water. It would probably depend on the extent of the overheating whether the corrugated roof went down. This much is to be noted, viz, that the external shell of the Wood fire box does not differ from the ordinary combination of flat and curved surfaces. The strength of any stayed surface is primarily that of the stays, provided the surface between the stays is not so extensive that the plate fails by bending.

With the stays pulled through the inner sheet, the ultimate destruction may be the collapse of the inner fire box or the explosion of the outer wrapper, or both.

We believe that the location of the stays in the bend of the corrugation tends to overheating, and owing to the depth of the corrugation and the partial inclosure of the end of the bolt in this corrugation, the tendency to accumulation of scale is greatly increased and the difficulty of removing this accumulation is also increased. This is borne out by the experience with the Wood box, the condition described having been very noticeable. In this respect we are decidedly of the opinion that the method of staying the Wood fire box is bad because the location of the bolt in the sheet is just where the maximum motion takes place and just where its presence increases the difficulty of proper cleaning. In addition, we are of the opinion that the increase in the bolt diameter, made necessary by the greater spacing of the stay bolts, is objectionable on account of the increased heating of the bolt and the difficulty of dispersing the heat.

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FACILITIES.

The point is made by Mr. Wood in his affidavit, transmitted to the committee by you, that from lack of proper facilities the New York Central fire boxes were constructed under very great difficulties, requiring from 500 to 600 heats to each box. This may be true and the performance may not have been that obtainable with boxes made under the best conditions. On the other hand, from the repair standpoint it may be presumed that the facilities were at least as good as those of the ordinary railroad shop, and the committee feels that the difficulties described by Mr. Wood fairly represent the conditions with which a road would have to contend in replacing the sheets of the Wood fire box.

CONCLUSIONS.

Your committee is very decidedly of the opinion that the Railroad Administration should not apply any of these fire boxes for the following reasons:

That the economy claims have not been proven.

That the life to be expected, based on the best performances, is very much less than that of the ordinary form of box.

That the time out of service will be very much greater than with the ordinary box.

Renewing fire boxes.—The fire box of a locomotive is one of the parts which usually has to be replaced several times during the life of the locomotive, each renewal involving considerable delay and expense. We believe that it would be a great mistake to add to the difficulties and expense of these renewals without positive evidence of benefits from the proposed construction.

Repairs of fire boxes.—The expense of preparing the necessary dies to form these boxes would be a very serious item of cost, and shops not having these facilities would experience great difficulties in making necessary repairs. Even patching, which with the ordinary box offers no great difficulty, would be an extremely difficult matter where the patch had to be clapped on to the corrugated surface. In the boxes observed, attempts had been made to correct service defects by autogenous welding, but without success.

Your committee does not believe that there is sufficient advantage in this form of construction to compensate for the above-mentioned disadvantages.

Respectfully submitted.

A. W. GIBBS,
Chairman.
JOHN PURCELL,
Member.
H. T. BENTLEY,
Member.

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THE WILLIAM H. WOOD
CORRUGATED LOCOMOTIVE FIRE BOX

Appendices to Report of November 12, 1918

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APPENDICES WITH REPORT ON WOOD'S CORRUGATED LOCOMOTIVE FIRE BOX.

CONSTRUCTION.

Letter October 7, 1918, Mr. John Purcell to Mr. A. W. Gibbs, discussing the construction of the Wood fire box.

WOOD FIRE BOX ON THE NEW YORK CENTRAL.

Letter October 9, 1918, Mr. A. J. Fries to Mr. A. W. Gibbs, with photographs showing the water side of the tube sheets of the three locomotives equipped with Wood fire boxes; and reports (nine) from October 22, 1910, to November 13, 1912, of the Performance of the Wood boxes; also reports August 25 and September 21, 1911, signed by Mr. Wood, of inspections of Wood fire boxes on two New York Central locomotives.

Reports August 31 and September 23, 1911, of examinations by Pennsylvania Railroad inspectors of Wood fire boxes on New York Central locomotives.

Letter September 14, 1918, Mr. H. L. Ingersoll to Mr. A. W. Gibbs, with report and statements covering so-called comparative tests of Wood fire boxes on the New York Central; records of stay bolts supplied and other work done on Wood fire boxes; and digest of Wood fire box situation on New York Central.

WOOD FIRE BOX ON THE UNION PACIFIC.

Letter from Mr. John Purcell to Mr. A. W. Gibbs, September 11, 1918; report of personal inspection of Wood fire box of Union Pacific engine No. 20, together with photographs (11) showing present condition; memorandum of reports from Union Pacific files on the performance of the Wood fire box while in service, showing the development of defects; and sketch showing distortion of flue sheet below main corrugation.

Letter from Mr. H. T. Bentley to Mr. Frank McManamy, September 4, 1918, inclosing report of Mr. T. F. Powers, general foreman, boiler maker, Chicago & North Western Railway, on inspection of Wood fire box of Union Pacific engine No. 20 at Omaha, August 30, 1918.

WOOD FIRE BOX ON ATLANTIC COAST LINE.

Letter from Mr. R. E. Smith to Mr. H. T. Bentley, April 13, 1918, giving history of the performance of the Wood fire box on Atlantic Coast Line engine.

OTHER DATA.

Letters March 20 and April 7, 1908, from Mr. George Hughes, chief mechanical engineer, Lancashire & Yorkshire Railway, England, to Mr. A. W. Gibbs, giving experience with corrugated firebox shown by print; also copies of correspondence between Mr. Wood and Mr. Hughes.

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REGARDING WOOD'S FIRE BOX.

ATCHISON, TOPEKA AND SANTA FE RAILWAY,
Albuquerque, N. Mex., October 7, 1918.

Mr. A. W. GIBBS,
Chief Mechanical Engineer,
Pa. R. R., Broad Street Station, Philadelphia, Pa.

DEAR MR. GIBBS: Further in connection with my letters of September 11 and 13 with reference to the Wood fire box.

There are several features of the Wood fire box which, in my judgment, either individually or collectively, will operate against a successful and satisfactory performance of this design of box.

First, the corrugated feature. While we know they increase the total heating surface of the corrugated sheets about one-third more than flat sheets of the same dimensions, it is not clear that there is any gain in the heating capacity for the reason that the depressed parts of the fire box corrugations are in retreat and on that account do not get the direct action of the flame.

I am inclosing blue print which shows a line through the corrugations marked "Heat line." All the surface above this line may be fairly considered as receiving heat from radiation only, and not very strong radiation at that, because the surface below the line must greatly lower the temperature of the heat flowing over it on its way to the flues.

I am also attaching photograph of a burned crown sheet which illustrates, in a marked degree, the difference between plate temperatures due to direct contact with the heat and the same plate getting radiated heat only. The photograph shows the top row of flue holes closed with sunflower plugs. The light-colored area below the three front rows of radials was in direct contact with the flame, and became red hot. The flame left the crown sheet at the third row of stays and went direct to the top flues, leaving the dark-colored portion to get radiated heat only. This is the usual condition of burned crown sheets except when top flues are close to the flange. The dark space, denoting low temperature, is narrow, sometimes extending from the first row of radials to flue sheet, but there is always a front portion of the crown sheet which does not get as hot as the center portion because the flame jumps across it to the flues, and there is no way this can be prevented in a corrugated box. Therefore, notwithstanding the increased total heating surface due to the corrugation, it is extremely doubtful if the heating capacity of such corrugated sheets is increased. The projecting corrugations get the full benefit of the flame and as a consequence do more work than the depressed corrugations which get heat only from radiation, and on account of evaporating more water, heavier scale forms on the water side, which, unfortunately, adds to the liability of excessive high temperature of the plate at those points. It seems also unfortunate that the stay bolts should be applied in these projecting corrugations for the reason that they add to the amount of heat which the plate surrounding them is required to take care of. The sketch attached shows the probable flow of heat through the stay bolt to the water. It will go the most direct way and naturally there will be a greater evaporation and incrustation at the junction of the stay bolt with the plate and greater liability of excessive heat on that account. In incrustating water this feature is fatal to a corrugated fire box.

The trenchlike formation of these fire-box plates and the stay-bolt application, which greatly aggravates the conditions, renders it practically impossible to devise any practical means for properly washing and cleaning or inspecting the water spaces. Hammering the fire side of the fire-box sheets at frequent intervals must necessarily be the only process for removing scale and preventing quick deterioration of the plates. The depressed corrugations, which do not accumulate much scale

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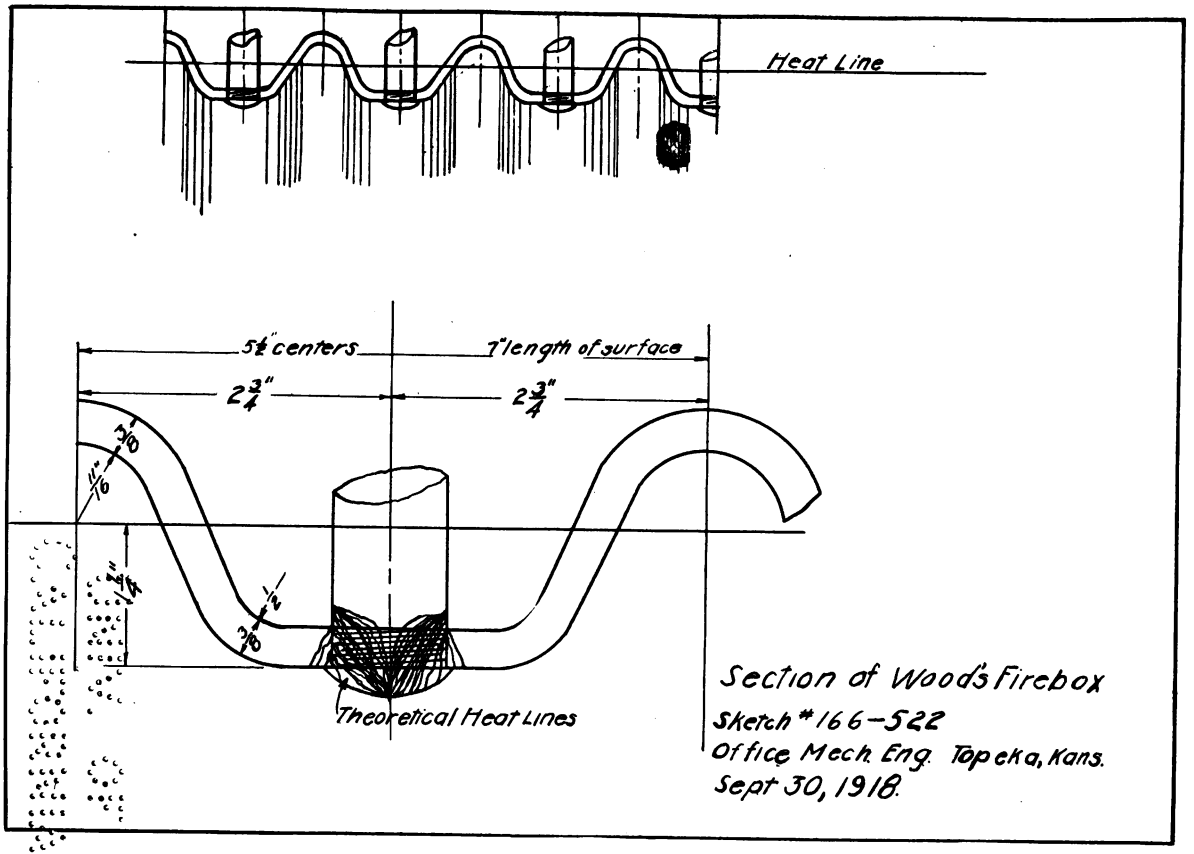

Section of Wood's Firebox
Sketch #166-522
Office Mech. Eng. Topeka, Kans.
Sept 30, 1918.

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and do not need so much cleaning, naturally get the full force of the washing water, while the corrugations which project into the fire are remote from the force of the washout water, which force is also further broken up by the stay bolts. There are only three washout holes on each side at the top of the boiler I inspected at the Omaha shops of the Union Pacific Co.

The theory of the corrugations is to also increase flexibility as well as increased heating surface. There is no question but what flexibility lengthwise, that is, fore and aft, is increased over that of the flat sheets, but the same corrugations add to the rigidity of the box vertically, and while the corrugations are a benefit in one direction, and increase flexibility, they are a positive detriment in adding to the inflexibility vertically.

The crown sheet of the fire box I examined has two plugged cracks, 107 cracks in the right side sheet, 28 of which were plugged, left has 95 cracks, 21 of which were plugged, and probably as many more incipient cracks. These cracks are all horizontal and all out from the stay-bolt holes, indicating that there is a sufficient bulging movement between the stay bolts which, added to the overheating of the plate around the stay-bolt holes, crystallizes the metal, and develops this cracking. It does not seem probable that this type of fire box will ever get away from that feature, which, in my judgment, is also fatal to the successful performance of the box.

The flue sheet in the box that I examined has a corrugation running all around it which, theoretically, should be a benefit in permitting flexibility and preventing deformation of the upper flange of the sheet. I found this top flange cracking on the water side about similar to what we now have in the standard flue sheet after three or four years service. This refers to the sheets in the heavy modern power in heavy service. There appears to be no advantage, so far as the top flange is concerned, over the standard straight flue sheet. The lower corrugation, which is under the flues, is badly distorted. It appears as though the sheet was trying to make a new corrugation toward the fire as there is practically an S-shaped, or double corrugation developed below the flue area. This was no doubt on account of the slack being worked from the top down, that is, when the flues were worked they usually started working them from the top and the slack concentrated at the bottom. Had they started working them from the bottom it is likely the slack would have gone to the top and there would have been more trouble there than is now shown.

As a general observation, it is extremely doubtful if projecting heating surface into the fire in a locomotive fire box will ever become popular. There is too much trouble with it. It does more work than the less prominent parts and must receive more care. The arch, or circulating tube, is an example of projecting heating surface. They must have special care with special tools to get good performance, and if the only function of the arch tube was to increase heating surface, the cost of maintenance would greatly exceed their benefit.

The corrugated side and crown sheets in the Wood's box are somewhat similar to the Jacobs-Shupert fire box, that is, the flexible and increased surface feature, but it lacks the low-water safety feature of the Jacobs-Shupert box, because it depend- for its support on stay bolts and radial stays, which are, or will be, affected by overs heating, and in case of low water an explosion tearing out the crown sheet will occur just the same as in the flat sheet box, while in the Jacobs-Shupert box the supporting stay sheets are in the steam and water spaces away from the heat of the fire, so that while one section may fail there is no probability of more than one failing.

Yours, very truly,

JOHN PURCELL.

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THE NEW YORK CENTRAL RAILROAD CO.,
MOTIVE POWER DEPARTMENT,
Depew, N. Y., October 9, 1918.

Mr. A. W. GIBBS,
Chief Mechanical Engineer, Pennsylvania Railroad,
445 Broad Street Station,
Philadelphia, Pa.

DEAR SIR: Referring to your recent visit at Depew concerning the Wood boilers.

We herewith hand you the photographs promised; also copies of some correspondence which you requested, and which will perhaps prove interesting.

Regretting the delay in forwarding these, which I assure you was entirely unavoidable, I am,

Yours, truly,

A. J. FRIES.

MEMORANDUM.

THE NEW YORK CENTRAL RAILROAD CO.,
Depew, N. Y., October 3, 1918.

Mr. A. J. FRIES:

Wood boiler applied to engine 2481 March 6, 1909, removed December 7, 1912, made 132,305 miles.

Wood boiler applied to engine 2490 December 5, 1908, removed August 24, 1912, made 131,666 miles.

Wood boiler applied to engine 2494 January 9, 1909, removed August 10, 1912, made 114,060 miles.

T. H. B.

A. W. G.:

Date removed is date they were turned out of Dunkirk Works of American Locomotive Co. after being converted to Mikado type.

Yours, etc.,

A. J. FRIES.

NEW YORK CENTRAL RAILROAD,
West Albany, October 22, 1910.

Mr. J. F. DEEMS,
G. S. M. P. & R. S. & M., New York.

DEAR SIR: Engines Nos. 2490 and 2494, which have the Wood's boilers, are now in the Depew shops undergoing repairs.

I inspected these boilers October 21 and found them in the following condition:

No. 2490. The corrugation at top of back flue sheet had a crack 24 inches long and is at least $\frac{5}{16}$ inch thick, the depth of crack being determined by clipping out a section of the defective metal. The corrugation at the bottom of the flue sheet is checked for a distance of 42 inches each side of center, the cracks being $\frac{1}{16}$ inch deep in places.

This sheet will have to be removed unless the defects can be welded with the oxygen-acetylene welding process.

The bottom of the first corrugation back of the flue-sheet seam at center of crown sheet shows signs of distress, and I believe it is only a matter of time when a crack will develop at this point.

The stay bolts and radial stays are leaking and will have to be rehammered and calked.

No. 2494. The corrugation at the top of back flue-sheet has a crack developing, which is 18 inches long and $\frac{1}{16}$ inch deep.

The corrugation at the bottom of the sheet is checked for a distance of 42 inches to the right of the center and 36 inches to the left of the center, the checks being about $\frac{3}{32}$ inch deep in places.

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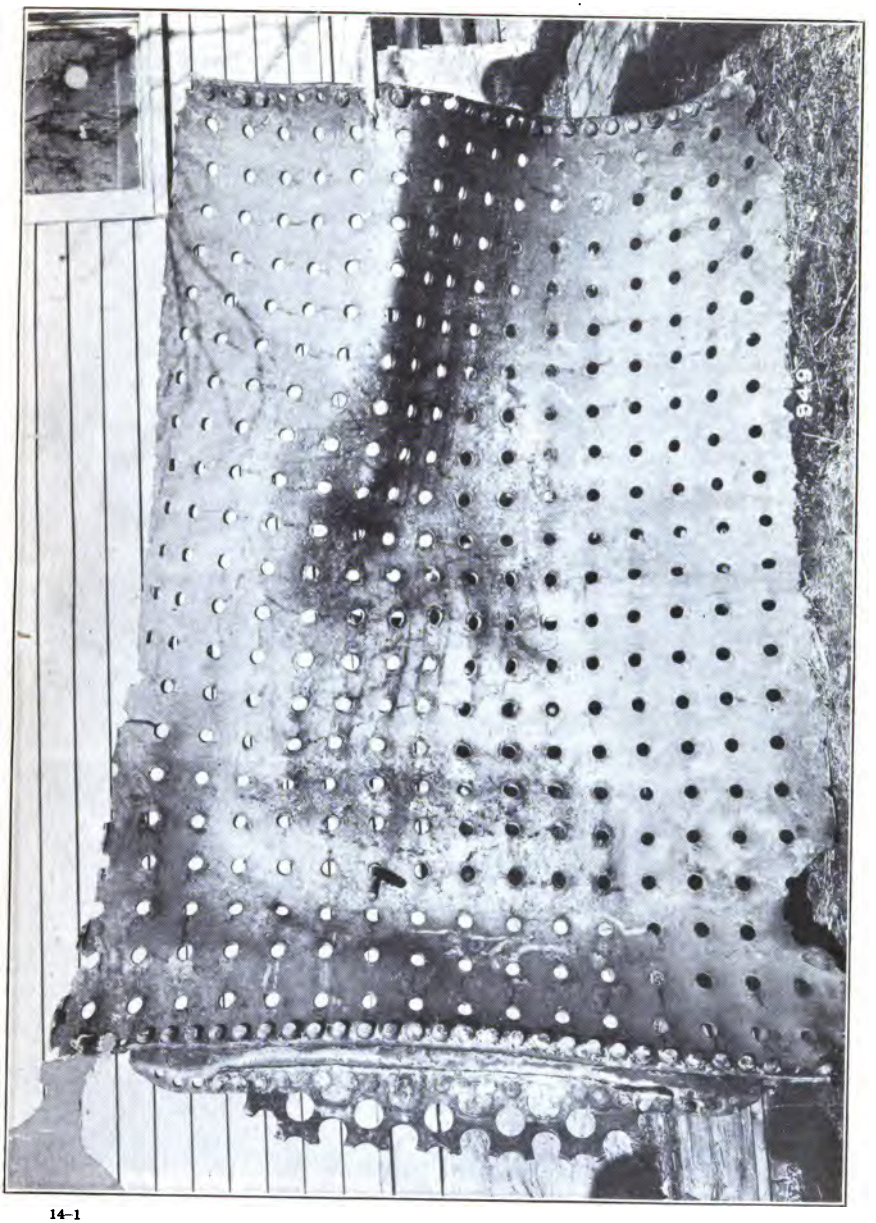

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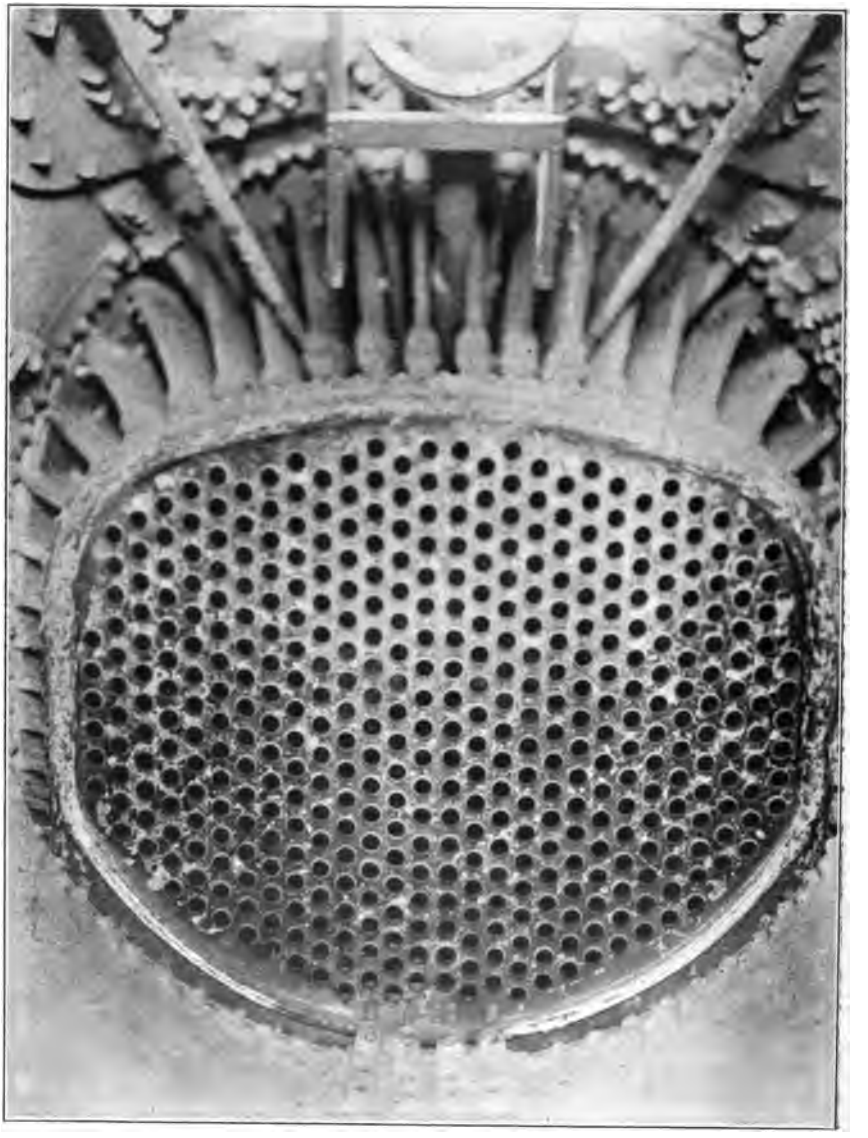

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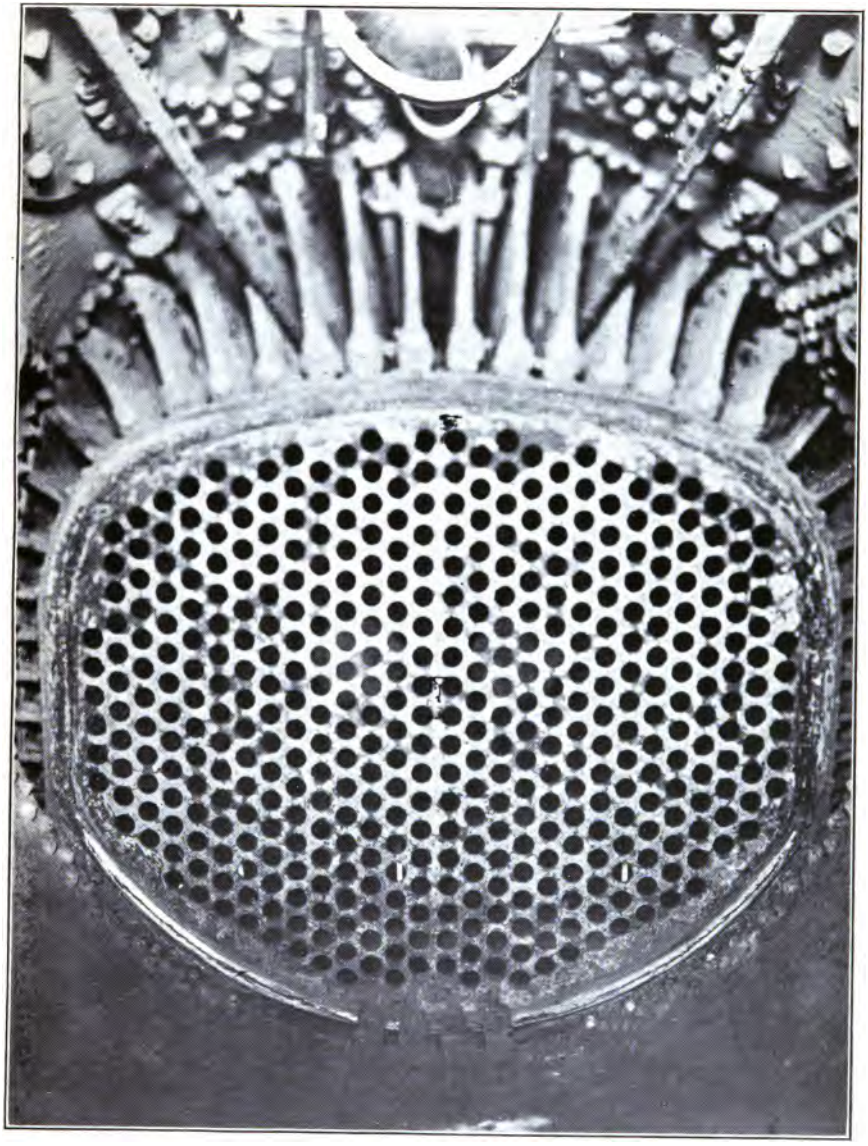

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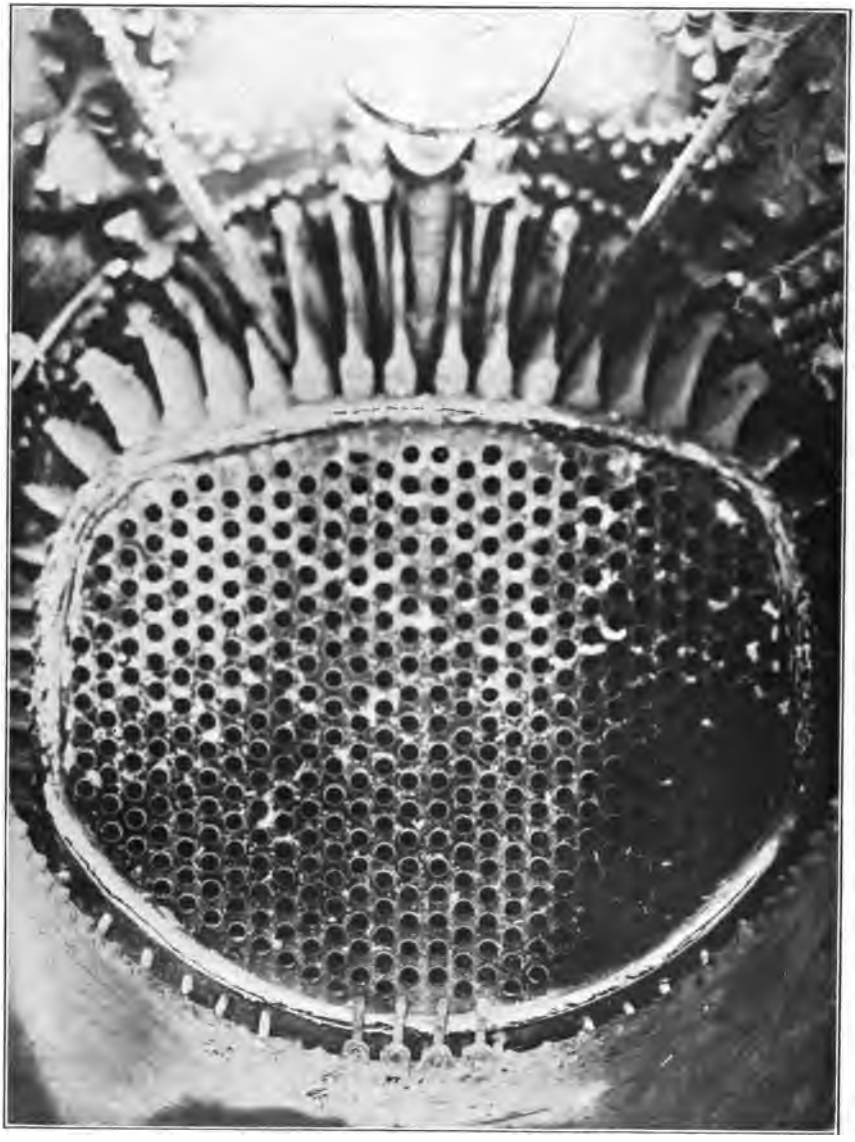

No. 2494.

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The small cracks have started to develop on the water side at the top of the left center water-tube hole. This is just opposite from what we have on ordinary flue sheets, on which cracks develop on the fire side at the bottom of the arch tube holes.

The stay bolts and radial stays are leaking and will have to be rehammered and calked.

The front flue sheets on both boilers are good and do not show any signs of cracking.

Scale ¼ inch thick has formed at the bottom of the corrugation in crown sheet, which proves there is not enough movement in the corrugation to break the scale.

Yours, truly.

(Signed) F. A. LINDERMAN,
Supervisor of Boilers.

NEW YORK CENTRAL RAILROAD,
Depew, N. Y., April 28, 1911.

Mr. JOHN HOWARD,
Superintendent of Motive Power.

DEAR SIR: Referring to your letter 529–H of February 16, also various correspondence since then regarding performance of engines Nos. 2481, 2490, and 2494 equipped with Wood boilers, as compared with three engines of a similar class with ordinary boilers, can advise as follows:

Engines 2487, 2492, and 2499 received overhauling about the same time the Wood boilers were placed in service, and were selected for a comparison, which was the best we could do under the circumstances. We, therefore, believe the comparison a rather unfair one on account of the age of the ordinary boilers as compared with the Wood, the ordinary being built in 1904, the Wood in 1908.

The engines went into service as follows:

Wood boilers.	Ordinary boilers.
Engine 2481, Mar. 6, 1909.	Engine 2487, July 23, 1907, new fire box.
Engine 2490, Dec. 5, 1908.	Engine 2492, Jan. 31, 1908, new fire box.
Engine 2494, Jan. 9, 1909.	Engine 2499, Feb. 12, 1910, ¾ new fire box.

The cost per mile for work done on boilers of both classes was taken for a period of nine months ending with December, 1910, and is as follows:

COST OF LABOR PER MILE AT ENGINE HOUSES.

Wood boilers.		Ordinary boilers.	
Engine 2481	0.0023	Engine 2487	0.0046
Engine 2490	.0054	Engine 2492	.0069
Engine 2494	.0055	Engine 2499	.0067
Total	.0132	Total	.0182
Average	.0043	Average	.0006

STAY BOLTS APPLIED.

Wood boilers.		Ordinary boilers.	
Engine 2481	4	Engine 2487	89
Engine 2490	4	Engine 2492	48
Engine 2494	19	Engine 2499	7
Total	27	Total	164
Average	9	Average	54

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From the above it would seem at first glance that the Wood boilers showed a decided superiority in the matter of broken stay bolts, but attention is again invited to an unfair comparison as to age of boilers.

As to coal consumed we can, of course, not give you any definite figures, but the opinion of our road foremen is that they decidedly use more fuel than others, which is caused principally by their constant tendency to leak, particularly, the radial stays, practically all of which leak badly with any variation of steam pressure.

It has also been very difficult to keep arch tubes tight, much more so than with ordinary or standard boilers.

Mr. Linderman made a personal inspection of the Wood boilers in October, 1910, to Mr. Deems and we attach herewith copy of his letter, which in our opinion is a clear indication that the life of the Wood fire boxes will be exceedingly short, in fact, we believe shorter than the standard box.

We also beg to call your attention to a public service commissioner's report of engine 2490 at Suspension Bridge, January 30, 1911, as follows:

"Engine 2490 has weak fire box and flues leaking. Engine out of service."

In conclusion we can not see where the Wood boilers show any advantage over the ordinary or standard type, except possibly in the matter of fewer stay-bolt troubles, and this advantage is so small as to be negligible.

We certainly would not advise extending the use of the Wood boiler.

Yours, truly.

D. S. M. P.

NEW YORK CENTRAL RAILROAD,
Depew, N. Y., July 7, 1911.

Mr. JOHN HOWARD,
Superintendent of Motive Power.

DEAR SIR: It is simply impossible to keep the water bars in the Wood boiler tight, and I would like your authority to remove them and patch the openings.

Yours, truly,
C-Mr. C. H. Hogan.

D. S. M. P.

NEW YORK CENTRAL RAILROAD,
Depew, N. Y., July 20, 1911.

Mr. JOHN HOWARD,
Superintendent of Motive Power.

DEAR SIR: Confirming conversation in my office yesterday, regarding engine 2494, equipped with Wood's boiler.

It is our intention to remove the water bars in this fire box at this shopping, as it has been found practically impossible to keep these water bars tight, due to the expansion and contraction of the box.

The same is true with the other two Wood boilers, and we will also remove the water bars from them at the next shopping.

I might add that the trouble with these bars have been so serious that in a number of cases we have had firemen refuse to go out on the engines.

Yours, truly,

D. S. M. P.

NEW YORK CENTRAL RAILROAD,
Depew, N. Y., August 29, 1911.

Mr. JOHN HOWARD,
Superintendent of Motive Power.

DEAR SIR: I hand you herewith report from Foreman Boiler Maker Mr. E. J. Hennessey regarding condition of boiler and fire box on engine 2494, which, as you know, has a Wood boiler:

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"I have made a personal inspection of boiler 2494, now in shop. I find the back flue sheet cracked on the heel of flange on bottom and along sides for a distance of 67 inches.

"The depth of crack at deepest point showed about $\frac{3}{16}$ inch deep.

"Three cracks on top of flue sheet, not serious.

"One crack, 14 inches, top of flue sheet, not serious.

"One crack, 3 inches, top of flue sheet, not serious.

"One crack, 1½ inches, top of flue sheet, not serious.

"The left middle water bar hole showed a crack about ½ inch long; the radial stays and stay bolts have been leaking.

"I find a heavy coating of scale in the corrugation on crown sheet, some of the scale about ¼ inch thick."

Yours, truly,

——— ———,

Dist. Supt. M. P.

NEW YORK CENTRAL RAILROAD.

REPORT ON ENGINE WITH WOOD BOILER IN DEPEW SHOPS FOR GENERAL REPAIRS AND HAVING TUBES FIXED OVER IN BOILER ON AUGUST 24, 1911. LAST REPORT OCTOBER, 1910. THIRD SET OF FLUES.

The boiler was thoroughly examined internally by C. J. Chester, and Mr. Hennessey, the New York Central superintendent of the boiler department, Depew shops, on August 22, 1911, and on the 23d by Edward Oldman, boiler maker for Farrar & Trefts, who made the boilers, and Fred. H. Snell, inspector for this company, Mr. C. F. Pierce, of New York City, Mr. Hennessey and Mr. William H. Wood being present.

The general condition of the boiler was conceded to be much the same as when examined internally October, 1910. The corrugation of fire box forming side and crown was examined very carefully and found free from any defects. It was noted the crown stay bolts showed having sweated after dumping of fires, but after lying on the branch from July 14 to August 21, when she was put in the shops for general repairs, it was found that more effective washouts might have kept crown sheet much freer from cake scale, same as the sides of the fire box which were clean. The back tube plate was examined carefully and tube holes were found round and in good form, *not distorted*—no cracks between bridges of tubes.

The corrugation on tube plate encircling tubes were carefully examined by the gauge from which they were made, and the center bottom was affected by expanding tubes, closing it inward from its shape as much as $\frac{3}{16}$ of an inch. This, with working under expansion and contraction, had caused an extension strain which showed a tendency to crack on one part for not more than 5 inches. There were one or two places in this part where a penknife blade might be inserted $\frac{3}{16}$ inch and to the right a line 33 inches, to the left one 34 inches, no part of which was $\frac{1}{64}$ inch deep. The part referred to as being 5 inches long can be fixed by the oxy-acetylene welder; therefore, it was not considerd these would in any way interfere with the working of the boiler until another set of flues are put in, when the same examination can be made again. No cracks were found between bridges of flues or on any part of the back flue sheet except these above mentioned.

From a careful stay-bolt test made by Mr. Chester it was found that two throat sheet stay bolts were broken, one on left first row under radius of throat sheet and one right, also one stay on each side of fire box at throat sheet end, about at the bottom of radius of fire-box crown sheet, also one in right corner of back sheet, and four in third row over center of fire doors on back sheet of fire box. These are the

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only stay bolts to be replaced since last shopped. The mud ring was examined and found tight and in first-class condition, as well as stay bolts on outside, which showed no appearance of leaking on outside wrapper sheet, nor did the rivets of the boiler shell.

The front tube sheet was found in perfect shape, with good flue holes and no cracked bridges, the corrugation corresponding with the gauges.

This data is being carefully noted by Mr. Wood in order that he may correct any defects that might appear in formation of fire boxes and tube plates during this test with engines 2481, 2490, and 2494, running on the New York Central between Buffalo, Lyons, and Syracuse, under bad water conditions. They started December 4, 1908.

This report is respectfully submitted by the undersigned.

(Signed) Wm. H. Wood.
(Signed) Edw. Oldman.
(Signed) Fred. H. Snell.

August 25, 1911.

New York Central Railroad.

CORRECTED REPORT ON ENGINE 2481 WITH WOOD BOILER IN DEPEW SHOPS FOR GENERAL REPAIRS AND TO HAVE TUBES FIXED OVER, SEPTEMBER 21, 1911. LAST REPORT OCTOBER, 1910. THIRD SET OF FLUES.

The boiler was thoroughly examined internally by C. J. Chester; Mr. Hennessey, superintendent of the boiler department of New York Central shops at Depew; Mr. Edward Oldman, superintendent boiler maker of Farrar & Trefts, who made the boilers; and Mr. Fred. H. Snell, inspector for this company, and by Mr. William H. Wood externally.

The back tube plate was in perfect form and the flue holes in tube plate free from any distortion or cracked bridges. The corrugation on tube plate was somewhat extended so that it would not permit the gauges to go over it. The bottom part of corrugation in the center showed some extension, caused by unequal expansion and contraction at this point, due from the distance from fire bars to lower tubes and corrugation in these boilers being so restricted that nearly 100 tubes, as well as corrugation, are blocked up by dead coal when at work, and the fire also being dead at this point is liable to admit cool air, thus causing undue stress by expansion and contraction of corrugation, as it also did on tube plate in boiler on engine 2494. The very same conditions occurred, and for a distance of 25 inches to left and 34 inches to right a tendency to extension by irregular lines was noted, just as a sheet would show where incrustation takes place when such conditions as these exist. This was not considered serious, as no part was over $\frac{1}{8}$ inch deep. The acetylene welding process can be applied to fuse to anneal this part of the corrugation, which was the only part of the corrugation affected, and there is no doubt in our minds that when these boilers are shopped for the fourth set of flues the conditions will not be materially changed.

The only stay bolts affected since last October are one in back head over left-hand door—broken—and one in the right side of throat sheet, first row from bottom of radius—broken.

There was no cake scale on side sheets, but on some parts over the crown sheet it showed about $\frac{3}{16}$ inch or less. Some of the crown bolts showed signs of leaking after the dumping of fires, but tube holes were not distorted, and from the external appearance all seams were tight. It was noted this and 2494 were the cleanest boilers we have ever inspected, being free from external leaks of any kind and having mud rings which were absolutely tight.

The tube plate in front is as good as the day it was put in. The back tube plate is also in perfect shape. The flue holes in boiler tube plates are round and free from

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any distortion with the exception of three holes in each corner of back tube plate, which are possibly $\frac{1}{32}$ inch out of round.

This report is a good one and is respectfully submitted by the undersigned.

(Signed) Wm. H. Wood.
(Signed) Edward Oldman.
(Signed) Fred. H. Snell.

September 21, 1913.

New York Central Railroad,
Depew, N. Y., March 11, 1912.

Mr. A. J. Fries,
Assistant Superintendent of Motive Power.

Dear Sir: We give you below copy of letter received from our boiler maker foreman, Mr. E. J. Hennessey, covering the condition of boiler of engine 2490 under date of March 8:

"On March 6, 1912, I made an examination of boiler of engine 2490; found the back flue sheet cracked on the head of corrugation on the bottom and both sides for a distance of 82 inches, and in one place it was cracked so bad you could put a knife blade in it a distance of full ¼ inch.

"The radial stays are heavily coated on bottom of stays where they screw into crown sheet fully $3\frac{1}{16}$ inches thick; crown sheet is also heavily coated with scale. The recess of the corrugation is filling up with loose scale.

"The front head sheet is O. K., being free from cracks; the leg of boiler is pitting quite bad just above the mud ring on fire-box side. Stay bolts and radial stays are leaking in fire box; side sheets are commencing to develop small checks from stay bolts in fire box.

"I would not recommend the welding of the back flue sheet."

Yours, truly,

———— ————,
Superintendent of Shops.

New York Central Railroad,
Oswego, N. Y., March 14, 1912.

Mr. John Howard,
Superintendent of Motive Power.

Dear Sir: As requested by you in your letter of the 11th instant, file 6617-H, I examined boiler of engine 2490 at Depew yesterday and find that the back flue sheet of this boiler is badly cracked for a distance of 82 inches in the bottom corrugation. The cracks are so opened in some places that it is possible to insert a knife blade ¼ inch in same.

The top corrugation of back flue sheet is starting to crack at different points. I also noted several cracks starting in the unions between the flue holes in the bottom of the sheet.

The first corrugation of crown-sheet back of flue sheet has started to check for a distance of 14 inches. This defect in crown sheet is not serious, but it will not be long before it will work through.

Owing to the general condition of the sheet and the crack at bottom corrugation being of such length, I do not think it would be advisable to try and weld this sheet, and would recommend that same be taken out.

For your information would say that the fire-box sheets are becoming quite badly corrugated on the water side just above the mud ring. I also noted that the fire-box sheets are starting to corrugate around the stay bolts.

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There are several cracks from the stay-bolt holes in both side sheets, which extend horizontally, whereas in the ordinary boiler cracks of this kind are nearly all vertical.

Yours, truly,

(Signed) F. A. LINDERMAN.

NEW YORK CENTRAL RAILROAD,
Depew, N. Y., April 12, 1912.

Mr. JOHN HOWARD,
Superintendent of Motive Power.

DEAR SIR: Attached herewith is a letter introducing Mr. J. J. Mansfield, chief boiler inspector of the Central Railroad of New Jersey.

Mr. Mansfield was given permission to examine the boiler of engine No. 2490 now in the shop, and it so happened that Mr. McAllister, chief boiler inspector of the Erie, was also here at the same time. They both scoffed at the idea of putting in a new flue sheet in this fire box on account of the condition of the rest of the box, and decidedly say that if the boiler was under their supervision they would not consider for a moment a new flue sheet.

A decidedly new and interesting development manifested itself, however, by this examination, and one which we had not thought of before, which is simply to the effect that even if we decided to put in a new flue sheet it could not be done without removing the entire fire box, and while it might be possible to remove the old sheet (which, however, is very doubtful), a new sheet could not be applied for the reason that the sheet is wider than the corrugation on the side sheets, and if we attempted to drop it down by the removal of frames it could not be done on account of the angularity of the throat sheet. The sheet is also wider considerably above the mud ring than at the mud ring itself.

Consequently a new sheet is entirely out of the question. This for your information.

Yours, truly,

_____,
Assistant Superintendent of Motive Power.

NEW YORK CENTRAL RAILROAD,
Depew, N. Y., November 13, 1912.

Memo. to Mr. JOHN HOWARD,
Superintendent of Motive Power:

Mr. Wood called here to-day with three representatives to examine the three Wood boilers now in Depew shop yard. One of these representatives was Mr. Oldman, now in the boiler business at Buffalo, and who as a former superintendent of Farrar & Trefts shop in Buffalo built these boilers.

The gentleman did not have very much to say; was somewhat surprised at the amount of opening of the cracks in the back flue sheets and now contends these flue sheets have given out about as he expected. I asked him point blank how he could renew these flue sheets and he replied that it could be done; that they had made a model of the sheets and that they could be gotten out all right. I admitted to him that they undoubtedly could be gotten out by distorting them probably, but did not understand how they could be replaced, to which he replied that it might probably be necessary to distort them a trifle to get them in, but that this was a comparatively easy matter as they could be warmed up and put back into their original shape after being in position in the boiler.

Later it developed that Mr. Oldman told our Mr. Hennessy that they had made some experiments to see whether these flue sheets could be gotten out or in, but the

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model they used to prove it was made of pasteboard, and he admitted that they could not be removed or applied without taking the mud ring out.

The old gentleman was very affable and very profuse in his thanks before he departed.

Yours, truly,

THE PENNSYLVANIA RAILROAD COMPANY,
Buffalo, N. Y., August 31, 1911.

Mr. R. N. DURBOROW,
General Superintendent of Motive Power.

DEAR SIR: As requested in your message of the 21st, we arranged to have an examination made of the Wood fire box in New York Central locomotive 2494 at the Depew shops on August 22, and I attach copy of report made by Mr. Chester, general stay-bolt inspector, also copy of a letter sent to Mr. Chester by Mr. Wood.

You will note there seems to be quite a variance between the report submitted by our general stay bolt inspector and the attached letter from Mr. Wood, and it seems to me that Mr. Wood intends to use his story of this examination for advertising purposes.

Yours, respectfully,

(Signed) WM. ELMER,
Superintendent of Motive Power.

OLEAN, N. Y., *August 24, 1911.*

Mr. J. M. HENRY,
Master Mechanic, Olean.

DEAR SIR: On making an examination of engine 2494 at the New York Central shops at Depew, I found in making an internal inspection that the back flue sheet is cracked on the bottom section in the center of the corrugation, running horizontal, measuring from the center of the flue sheet to the left side 33 inches long, and to the right 34 inches long, from my judgment to be about $\frac{1}{16}$ inch and less in depth, and on the top of the sheet in the center of the corrugation, I found three cracks running horizontal; one crack 14 inches long, one 3 inches long, and one 1½ inches long, but these cracks do not seem to be over $\frac{1}{16}$ inch deep. I also found ¼ inch and less of scale in between the corrugation on crown sheet, causing all radial stays to leak and a number of the stay bolts, counting the stay bolts from the center of crown sheet, there were 11 rows leaking each side of the center.

On examining the stay bolts, I found two broken and six leaking in the telltale holes in the throat sheet, six leaking in the telltale holes in the door sheet, and four in the side sheets—two on the right side and two on the left side.

There were a few of the flue holes in the upper corners of the back flue sheet that were out of round $\frac{1}{32}$ of an inch, and the sheet is warped $\frac{3}{16}$ inch on the bottom half. All seams in the fire box and around the mud ring were in good condition and showed no signs of leakage.

Yours, truly,

(Signed) CHAS. J. CHESTER,
General Stay Bolt Inspector.

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NEW YORK CENTRAL RAILROAD,
Buffalo, N. Y., September 23, 1911.

Mr. R. N. DURBOROW,
General Superintentent of Motive Power.

DEAR SIR: As requested in your message of the 19th, we had Mr. Chester examine Wood fire box of New York Central locomotive 2481 at Depew on the 21st instant, and attached is a copy of his report.

Yours, respectfully,

(Signed) WM. ELMER,
Superintendent of Motive Power.

OLEAN, N. Y., *September 22, 1911.*

Mr. J. M. HENRY,
Master Mechanic, Olean.

DEAR SIR: On making an examination of Mr. Wood's fire box of engine 2481 at the New York Central shops at Depew I found in making an internal inspection that the back tube sheet is cracked on the bottom section in the center of the corrugation running horizontal, measuring from the center of the tube sheet to the right side 34 inches long and to the left 25 inches long, then a space of 4 inches and another crack of 4 inches long. These cracks appear to be about $\frac{1}{16}$ inch and less in depth. There were no signs of cracks on top section of tube sheet. I also found $\frac{1}{16}$ inch and less of scale in between the corrugation of crown sheet, causing all the radial stays to leak. Counting the stays from the center of the crown sheet there were nine rows leaking each side of the center.

On examining the stay bolts I found two broken—one in throat sheet, three bolts down from the right hand top corner, and one in door sheet, top row, second row from the left side; also five stay bolts leaking in telltale hole—three in right side sheet and two in top row of door sheet.

There were a few of the tube holes in the upper corner of back tube sheet that were out of round $\frac{1}{32}$ inch, the tube sheet being perfectly straight. All seams in fire box and around mud ring were in good condition, and showed no signs of leaking, with the exception of crack in bottom of mud ring in the right back corner had been giving some trouble. It looked to be welded at this corner and had opened up.

Yours, respectfully,

(Signed) CHAS. J. CHESTER,
General Stay Bolt Inspector.

ALTOONA, PA., *September 19, 1911.*

Subject: New York Central locomotive No. 2481 with Mr. William H. Wood's patent boiler—Examination of.

Mr. R. N. DURBOROW,
General Superintendent of Motive Power.

DEAR SIR: I have read the report signed William H. Wood, dated August 25, 1911; also copy of report signed by Charles J. Chester, general stay bolt inspector, dated Olean, N. Y., August 24, 1911, as well as letter addressed to you, signed William Elmer, dated August 31, 1911 all relating to Wood fire box in New York Central locomotive No. 2494. Also a meassge to you from Mr. William H. Wood, dated Media, Pa., September 19, 1911, and relating to examination of New York Central locomotives Nos. 2494 and 2481, stating that the latter can be examined early Thursday morning next, at Depew Shops, N. Y., by leaving to-night for Depew. I would suggest that the boiler of this locomotive, No. 2481, be examined and that it be done by Mr. Charles J. Chester, who examined the boiler of locomotive No. 2494.

Yours, respectfully,

(Signed) A. S. VOGT,
Mechanical Engineer.

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OFFICE OF REGIONAL DIRECTOR EASTERN RAILROADS,
New York, September 14, 1918.

Mr. A. W. GIBBS,
Chief Mechanical Engineer, P. R. R.,
Philadelphia, Pa.

Mr. JOHN PURCELL,
Assistant to Federal Manager, A. T. & S. F. R. R.,
Chicago, Ill.

GENTLEMEN: Replying to your respective letters of August 24th, I hand you herewith the following papers relative to Woods' fire box:

(1) White prints giving figures from the test.
(2) Memorandum analyzing these figures.
(3) Report of inspection of fire box.
(4) Digest of the situation made by General Attorney Lyman for Mr. A. H. Smith. This fire box is at Depew, N. Y.

Yours, very truly,

H. L. INGERSOLL.

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Comparative Tests, New York Central & Hudson River Railroad.

Wood's fire box with arch tubes, versus standard fire box without arch tubes.

SUMMARY, 1909.

No.	Item.	"Wood" boiler.				Standard type.			
1	Division	Western.	Western.	Western.	Western.	Western.	Western.	Western.	Western.
2	Direction of run	*East.*	West.	*East.*	West.	*East.*	West.	*East.*	West.
3	Date	Dec. 10	Dec. 12	Dec. 18	Dec. 19	Dec. 6	Dec. 4	Dec. 14	Dec. 15
4	Engine number	2494	2494	2490	2490	2485	2485	2438	2438
5	Cars hauled	67	84	67	66	71	75	51	79
6	Tons hauled	2,839	1,621	2,540	1,296	2,794	1,345	2,741	1,349
7	Miles run	149.55	148.98	147.75	148.60	125.94	147.69	147.46	117.93
8	Ton-miles	424,572.45	241,496.58	375,285.00	192,585.60	351,876.36	198,643.00	404,187.86	159,087.57
9	Time on road	13 h. 41 m.	12 h. 41 m.	14 h. 49 m.	13 h. 47 m.	12 h. 33 m.	11 h. 28 m.	12 h. 20 m.	13 h. 20 m.
10	Standing time	3 h. 13 m.	3 h. 3 m.	4 h. 49 m.	3 h. 34 m.	3 h. 46 m.	2 h. 13 m.	2 h. 41 m.	4 h. 8 m.
11	Running time	10 h. 28 m.	9 h. 38 m.	10 h. 0 m.	10 h. 13 m.	8 h. 47 m.	9 h. 15 m.	9 h. 39 m.	9 h. 12 m.
12	Ton-miles per hour	40,559.31	25,077.50	37,528.50	18,843.90	40,065.96	21,466.20	41,884.70	17,291.10
13	Drifting time	1 h. 24 m.	29 m.	1 h. 10 m.	28 m.	1 h. 26 m.	42 m.	1 h. 41 m.	21 m.
14	Working time	9 h. 4 m.	9 h. 9 m.	8 h. 50 m.	9 h. 45 m.	7 h. 19 m.	8 h. 33 m.	7 h. 58 m.	8 h. 51 m.
15	Average position of throttle	.27	.31	.26	.21	.30	.28	.31	.267
16	Average position of reverse lever in cut-off as fraction of the stroke	.46	.41	.40	.38	.46	.37	.36	.40
17	Speed miles per hour, Maximum	38	38	39	30	47	34	42	27
	Speed miles per hour, Average	14.29	15.47	14.77	14.55	14.37	15.96	15.28	12.70
18	Draft, inches, water, Maximum	9.0	8.5	7.5	9.0	8.0	8.0	8.5	7.0
	Draft, inches, water, Average	4.68	5.24	5.24	5.41	4.95	5.23	4.68	4.34
	Draft, inches, water, Minimum	1.0	2.0	1.0	.5	.5	.8	1.0	.5
19	Boiler pressure, pounds per square inch gage, Maximum	230	215	205	210	210	210	220	220
	Boiler pressure, pounds per square inch gage, Average	184.82	171.82	177.02	180.267	175.00	185.00	207.24	202.98
	Boiler pressure, pounds per square inch gage, Minimum	135	105	140	120	120	155	185	170
20	Temperature, front end, ° F., working, Maximum	735	735	705	735	680	715	615	585
	Temperature, front end, ° F., working, Average	624	638	624	648	570.6	611	546	488
	Temperature, front end, ° F., working, Minimum	455	485	505	455	445	475	455	255
21	Average temperature of air, ° F	27.0	21.0	25.0	22.0	33.6	35.0	33.0	30.0
22	Average temperature of tank water, ° F	60.00	46.00	39.36	40.00	43.50	39.50	40.00	37.75
23	Total foot-pounds expended	11,205,775,000	11,745,675,531	10,825,678,355	11,169,113,362	9,025,030,309	10,924,760,775	9,327,170,075	10,602,141,785
24	Average drawbar horsepower	624.207	648.320	618.960	578.560	622.974	645.320	591.300	605.040
25	Drawbar horsepower hours	5,655.315	5,932.128	5,465.410	5,640.960	4,553.940	5,517.480	4,712.660	5,354.604
26	Coal fired, total in pounds	36,200	36,400	35,900	36,300	29,800	34,200	34,700	37,000
27	Per cent combustible, by analysis	92.46	90.37	92.97	92.62	91.77	90.10	90.77	88.77
28	Total combustible fired, pounds	31,797.00	31,348.45	31,941.05	31,301.21	27,347.46	30,814.20	29,922.33	32,844.90
29	Total dry coal fired, pounds	34,390.0	34,689.0	34,356.3	33,795.3	29,800.00	34,200.0	32,965.0	37,000.0
30	Pounds of coal used per hour	3,460.80	3,779.80	3,590.00	3,555.33	3,394.07	3,697.29	3,595.80	4,021.73
31	Pounds of combustibles, used per hour	3,036.9	3,255.3	3,194.1	3,062.7	3,114.7	3,331.26	3,094.3	3,570.0
32	Pounds of dry coal, used per hour	3,287.80	3,602.10	3,435.63	3,310.01	3,394.07	3,697.29	3,416.06	4,021.73

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33	Pounds of coal used per drawbar horsepower hour.	6.400	6.136	6.654	6.430	6.543	6.193	7.363	6.900
34	Pounds of combustible used per drawbar horsepower hour	5.620	5.280	5.840	5.540	6.005	5.584	6.340	6.130
35	Pounds of dry coal used per drawbar horsepower hour	6.080	5.840	6.283	5.991	6.543	6.193	6.994	6.900
36	Pounds of coal used per square foot of grate surface, per hour	62.92	68.72	65.27	64.64	61.82	67.34	65.49	73.25
37	Pounds of combustible used per square foot of grate surface, per hour	55.21	59.18	58.07	55.68	56.73	60.67	56.48	65.02
38	Pounds of dry coal used per square foot of grate surface, per hour	59.77	65.49	62.46	60.18	61.82	67.34	62.20	73.25
39	Pounds of coal used per square foot of heating surface, per hour	.911	.996	.946	.936	.868	.945	.920	1.029
40	Pounds of combustible used per square foot of heating surface, per hour	.8002	.858	.841	.807	.796	.851	.793	.913
41	Pounds of dry coal used per square foot of heating surface, per hour	.866	.949	.905	.872	.868	.945	.874	1.029
42	Pounds of coal used per ton-mile, per hour	.89	1.45	.95	1.92	.74	1.59	.83	2.14
43	Pounds of combustible used per ton-mile, per hour	.78	1.25	.85	1.66	.68	1.43	.71	1.89
44	Pounds of dry coal used per ton-mile, per hour	.85	1.38	.91	1.79	.74	1.59	.78	2.14
45	British thermal units per pound of dry coal	14.500	14.200	14.650	14.560	14.400	14.160	14.270	13.940
46	Total B. t. u.'s liberated	498,655,000	492,583,800	503,319,795	492,059,568	429,120,000	484,272,000	470,410,500	515,780,000
47	B. t. u.'s utilized	281,390,004	298,067,028	323,817,690	311,852,814	260,026,914	278,712,252	285,069,498	308,402,262
48	B. t. u.'s expended per drawbar horsepower hour	88.174	83.037	92.091	87.229	94.229	87.770	99.818	96.324
49	Pounds of water evaporated, total	240,540	252,090	272,190	262,250	219,380	234,000	238,950	258,090
50	Pounds of water evaporated per pound of coal, as fired	6.64	6.92	7.57	7.22	7.36	6.84	6.88	6.97
51	Factor of evaporation	1.211	1.224	1.232	1.231	1.227	1.233	1.235	1.237
52	Pounds of water evaporated per pound of coal (as fired) from and at 212° F	8.041	8.470	9.320	8.890	9.030	8.430	8.490	8.652
53	Pounds of water evaporated per pound of combustible (as fired) from and at 212° F	9.161	9.842	10.494	10.313	9.840	9.363	9.862	9.720
54	Pounds of water evaporated per pound of dry coal (as fired) from and at 212° F	8.473	8.900	9.750	9.552	9.030	8.430	8.952	8.652
55	Pounds of water evaporated (from and at 212° F.) per square foot heating surface, per hour	7.338	8.440	8.833	8.331	7.840	7.977	7.827	8.881
56	Pounds of water evaporated per drawbar horsepower hour	42.59	42.49	49.76	46.49	48.17	42.41	50.703	48.38
57	Boiler horsepower	807.10	928.70	971.63	916.49	888.60	903.10	886.39	1,005.85
58	Boiler efficiency, per cent	56.4	60.5	64.3	63.3	60.5	57.5	60.6	59.7
59	Foot-pounds developed per B. t. u	22.47	23.84	21.50	22.69	21.03	22.55	19.82	20.50
60	Locomotive efficiency, per cent	2.887	3.060	2.760	2.910	2.700	2.900	2.540	2.640

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COMPARATIVE TESTS, NEW YORK CENTRAL & HUDSON RIVER RAILROAD—Contd.

Wood's fire box with arch tubes, versus standard fire box without arch tubes—Continued.

RECAPITULATION, 1909.

No.	Item.	"Wood."	Standard.	Per cent difference.	
				Increase.	Decrease.
1	Division	Western.	Western.		
2	Ton-miles, total (train weights as per conductor's wheel reports).	1,233,939	1,113,794	11.1	
3	Standing time, total	14 h. 39 m.	12 h. 48 m.	14.45	
4	Running time, total	40 h. 19 m.	36 h. 53 m.		
5	Ton-miles per hour, average	30.502	30,176		
6	Speed, miles per hour, average	14.77	14.5		
7	Position of throttle, per cent of full opening, average.	26	28.9		
8	Position of reverse lever, per cent of full-stroke cut-off, average.	41	39.75		
9	Boiler pressure, average	178	192		7.29
10	Draft, inches of water, average	5.14	4.8	7.08	
11	Temperature in smoke box (while working), average.	633	553	14.46	
12	Water evaporated per square foot of heating surface per hour from and at 212° F.	8.234	8.131	1.27	
13	Water evaporated per pound of combustible per hour from and at 212° F.	9.952	9.696	2.64	
14	Pounds of coal per square foot of grate surface per hour.	65.39	66.97		2.83
15	Pounds of coal per ton-mile per hour	1.302	1.325		1.73
16	Pounds of coal per drawbar horsepower, hour	6.405	6.749		5.09
17	Pounds of water per drawbar horsepower, hour	45.334	47.415		4.38
18	British thermal units per pound of dry coal (by analysis), average.	14,477	14,192	2.01	
19	Drawbar horsepower, average	617.512	616.158	.219	
20	Boiler horsepower, average	906	920		1.52
21	Boiler efficiency, per cent	61.125	59.575	2.6	
22	Locomotive efficiency, per cent	2.902	2.695	7.77	
23	British thermal units per pound of water evaporated from and at 212° F.	1,579.3	1,620.5		2.54
24	Pounds of water per pound of coal (as fired) (actual evaporation per pound of coal).	7.0875	7.0125	1.07	
25	Pounds of dry coal per square foot of grate surface per hour	61.97	66.15		6.31

In the per cent difference column the standard engine is taken as the basis of comparison.

INFORMATION DRAWN FROM ATTACHED BLUE-PRINT RECORD OF SO-CALLED TESTS ON NEW YORK CENTRAL RAILROAD OF SOME BOILERS EQUIPPED WITH SPECIAL FIRE BOXES IN 1909.

The tests consist of two round trips in freight service on one division. The trainloads were not engine ratings and were not equated for resistance over what is practically a level-track division. I can not find how the coal or water were measured.

The tests were made without my knowledge; that is, I did not happen to know of them at the time.

It is noted from the record that the engines equipped with special fire boxes show a total of 22,692 drawbar horsepower hours. In both instances the record shows more horsepower hours in westbound trip with light train than in eastbound trip with heavy train.

The drawbar horsepower hours with standard fire boxes were 20,136.

Taking the ton mileage in each case as shown, we have 54.4 ton miles per horsepower hour with the special fire boxes and 55.3 ton miles per horsepower hour with the standard fire boxes.

At this period, with the class of power tested, the standard rating was 3,300 tons eastbound trainload. The tonnage actually used in these tests was, respectively, 2,839, 2,540, 2,794, and 2,791. In other words, the special fire-box locomotives took

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2,839 tons and 2,540 tons, a total of 5,379 tons, and the standard locomotive took 2,794 tons and 2,791 tons, a total of 5,535 tons, in two trips in each case.

Unfortunately, the locomotive that had the smallest tonnage eastbound shows the largest amount of running time; that is, the running time for the two trips of the special fire-box locomotive was 13 hours, 41 minutes and 14 hours, 49 minutes, a total of 28 hours, 30 minutes and that of the locomotive with the standard fire-box in one case was 12 hours 33 minutes, and in the other 12 hours 20 minutes, a total of 24 hours 53 minutes.

Standing time was a total of 8 hours 2 minutes for the special fire-box locomotive on eastbound trips and 6 hours 27 minutes for the standard fire-box locomotive on the two trips.

You will appreciate that the westbound trains are simply a balancing condition, and it has never been the practice to run tonnage trains west because of the fact that this would mean the movement of light power. In other words, the controlling factor in the business being east and the loaded movement being east, tonnage trains are run east and what there is to go west, broadly speaking, would be reasonably divided up among the number of locomotives returning west to get a balance of power.

When you examine the fuel consumption on these eastbound trips (where the work was really done) you have with the special fire-box locomotive 31,797 pounds and 31,941 pounds, making total of 63,738 pounds, in order to move east a total of 5,379 tons. With the standard fire-box locomotive you have for the eastbound trips 27,347 pounds and 29,922 pounds, or a total of 57,269 pounds, to move 5,535 tons. In other words, the special fire-box locomotive used 6,500 pounds more fuel to move 156 less tons of freight over the road.

I have merely analyzed the figures eastbound to show how the point of view may differ and may throw a new light on the whole situation.

I thought you would appreciate getting these logs so that you might have the basic record analyzed for your use and for your more complete information on the subject.

I am told the boilers are at Depew and have not been in service for some years, and that the practical judgment of the people who saw the boilers and knew about the test was skeptical as to any merit in the design and as to what degree of risk might be involved in this departure from the standard in view of their previous experience with fire boxes.

DEPEW, N. Y., *February 21, 1912.*

Referring to your letter 5211–H of February 9 and returning correspondence relative to Wood's boilers. We give you below record of stay bolts applied to these boilers and other work done while at the shop.

These records, however, do not extend previous to January 1, 1910, as all such previous records were destroyed in the fire of the office building.

ENGINE 2490.

Boiler applied December, 1908.

Engine last in shop November, 1910, at which time the condition was as follows:

Corrugation at back of top flue sheet has crack 24 inches long and the corrugation at bottom of flue sheet cracked for a distance of 42 inches each side of center.

The bottom of first corrugation back of flue sheet seam at center of crown sheet showed at that time signs of distress, and it was our opinion then that crack would develop at this point in a course of time.

The sheet was repaired by means of the oxy-acetylene process and engine is now in Depew shop yard waiting shop in poor condition both as to flues and machinery.

Total number of stay bolts renewed since application of boiler, 62.

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ENGINE 2481.

Boiler applied March, 1909.

Engine last in shop October, 1911, at which time it showed the following condition:

Two broken and four fractured stay bolts; one crack in back flue sheet flange 53 inches long; all button head radial stays leaking badly; right back corner of mud ring broken and welded with the acetylene process; water bars removed and patches welded in water bar holes over flue sheet and door sheet; crack in flue-sheet flange: also welded by oxy-acetylene process.

Total number of stay bolts renewed since application of boiler, 36.

ENGINE 2494.

Boiler applied January, 1909.

Last in shop in September, 1911.

Back flue sheet cracked in flange 65 inches long.

Ten broken and 11 fractured stay bolts renewed.

All radial stays leaking badly and recalking and all other stay bolts in fire box reriveted.

Water bars removed and patches welded over water bar-holes on flue and door sheets.

Total number of stay bolts renewed since application of boilers, 50.

To this we might add that the only favorable thing we can say about the Wood boiler is the freedom from broken stay bolts as compared with the ordinary type. This, however, is largely offset by the continuous leaking of these bolts as well as the radial stays due to the expansion and contraction of the fire boxes by variations of steam pressure.

You will note that we also removed the water bars on engines 2481 and 2494, which was made necessary by the fact that we could not keep them tight, and in one or two instances firemen refused to go out on the engines on account of them leaking.

Flues do not last any longer than in the ordinary type of boiler, neither do they steam any better and neither is there any economy in fuel.

It is also our opinion that the back flue sheets in all of them will have to be renewed at the next shopping.

Yours truly,

(Signed) A. J. FRIES,
Assistant Superintendent of Motive Power.

NEW YORK CENTRAL & HUDSON RIVER RAILROAD CO.,
Depew, N. Y., November 27, 1911.

TEST NO. 907.

MR. JOHN HOWARD,
Superintendent of Motive Power.

DEAR SIR: Referring to your letter 2219–H of November 15, regarding Test No. 907, which is the Wood boiler test, can advise:

These locomotives were operated in through freight service until flues began to give trouble, when they were placed in local service.

Engine 2481 passed through the main shops in October and since that time has been assigned to the Buffalo-Pekin run and has given good service.

Engine 2490 has been out of the shop about 12 months and is at present on a local run between De Witt and Syracuse, not in good condition.

Engine 2494, which passed through the shop in September, developed a crack in flue sheet and is now out of service. This crack was 65 inches long circumferentially and was welded with the acetylene process when engine was last in the shop.

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We can say positively that these engines can not give any better service than the standard, except perhaps that they have not had as many broken stay bolts. They, however, have given considerable trouble on account of cracks in heel of flange of flue sheet. The flues do not last any longer; in fact, we are of the opinion that they do not last as well, as the heads give evidence of pulling off on bottom of boilers and on both outside rows on flue sheet, no doubt caused by expansion of flue sheet.

The principal trouble with the Wood boiler, in our opinion, is due to crown bolts and stay bolts leaking continuously in fire box, particularly when there is any drop in steam pressure.

I give you below the last physical examination and test of engines 2481 and 2494. Engine 2490 is not included as it has been out of the shop about 12 months.

Engine 2481: Two broken and four fractured stay bolts renewed; one crack welded in flue sheet flange 53 inches long; all button head radial stays calked; stay bolts in fire box riveted; right back corner of mud ring welded; water bars removed and patched welded in water-bar holes in flue sheet and door sheet.

Engine 2494: Ten broken and 11 fractured stay bolts renewed; one crack welded in flue-sheet flange, 65 inches long; all button head radial stays calked; stay bolts in fire box riveted; water bars removed and patched welded in water bar holes on flue and door sheet.

Yours, truly,

(Signed) A. J. FRIES,
District Superintendent of Motive Power.

MARCH 11, 1912.

MR. A. H. SMITH,
Vice President and General Manager.

DEAR SIR:—With reference to pending matters with Mr. William H. Wood, president of the William H. Wood Loco Fire Box and Tube Plate Co., I beg to send herewith a draft letter to Mr. Wood for your signature. I have been through the record very carefully, and have been over this letter and the situation with Mr. Howard, and the letter meets his approval.

If it could be consistently done, the preferable course would be, perhaps, to pay no attention to his letter, but he keeps writing to President Brown, and I think, therefore, we have got to say something to him.

Very truly yours,

ALEX. S. LYMAN,
General Attorney.

MARCH 12, 1912.

MR. WILLIAM H. WOOD,
President, the William H. Wood Loco Fire Box and Tube Plate Co.,
Media, Delaware County, Pa.

DEAR SIR:—Your letters to Mr. W. C. Brown, with reference to the boilers which this company purchased from you, have been referrred to me. The delay in this reply is due to the fact that I have had a rather thorough investigation made of the facts of the case, involving the going over of somewhat voluminous correspondence and data. I think the following propositions are distinctly made out from the record mentioned:

1. The boilers in question were purchased from your company on precisely the same basis on which we purchase other material used in the maintenance and operation of the railroad; that is, there was no agreement that any definite experiments, or tests or observations should be made of the boilers in question, with participation on the part of your representatives. Of course, the fact remains that the boilers involved some novel principles of construction, and under the circumstances our motive power

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department would naturally desire to satisfy itself of the value, or otherwise, of the device.

2. I am satisfied that the experiments, tests, and observations made of this boiler by the motive power department have been thorough and fair, and that there has been no ulterior motive involved, as perhaps suggested in some of the correspondence, but an honest desire to ascertain the actual results.

In connection with the experiments, tests, and observations made, I note that your representatives have been shown unusual courtesies, and have been accorded privileges which are ordinarily denied the representatives of manufacturers who sell goods to this company.

3. I beg to inclose copy of the letter addressed to Mr. John Howard, superintendent of motive power, by District Superintendent of Motive Power A. J. Fries, which fairly represents the views of our motive power department with reference to this type of boiler.

As you are doubtless aware, a number of other railroads have sent inquiries as to our view of the superiority or efficiency of these boilers over the standard type. I have not given them any direct information, except to say that representatives of the motive power departments of such companies were at liberty to investigate the locomotives for themselves, and observe their actual performance. I have accordingly treated the report of Mr. Fries as confidential, and I assume that, under the circumstances, you would desire to maintain the same attitude toward it.

Very truly yours,

INSPECTION OF WOOD'S FIRE BOX.

THE ATCHISON, TOPEKA & SANTA FE RAILWAY SYSTEM,
Topeka, Kans., September 11, 1918.

MR. A. W. GIBBS,
Chief Mechanical Engineer,
P. R. R., Broad Street Station,
Philadelphia, Pa.

MY DEAR MR. GIBBS: In accordance with my letter to you of August 27 on the subject inspection of Wood's fire box, which was formerly in service on an engine on the Union Pacific Railroad, I visited the Union Pacific shops at Omaha on Saturday, September 7, 1918, and had 11 photographs taken of different parts of the box, copies of which I take pleasure in handing you herewith. I have had shown at the bottom of the photographs explanation of the defects.

I am also inclosing copy of memorandum report secured from files on the Wood's corrugated fire box as applied to Union Pacific engine No. 20. This box was applied to the locomotive and went into service on the third district of the Nebraska division of the Union Pacific Railroad on April 14, 1910, and was removed in May, 1912. I asked Mr. Fuller's office on Saturday, the 7th, for some further information regarding the test as to water conditions, etc., and they were to have it reach me to-day, but it has not as yet been received. As the time is getting short I thought it advisable to send you what information I had and in case the other information is received will forward it to you promptly.

I am quoting below some memorandums taken while making inspection of the box, and am also inclosing a sketch showing some additional information in case you do not have blue print of the box:

At mud ring box is 66½ inches wide and 108 inches long.
From corrugation to mud ring at back, 64 inches.
From corrugation to mud ring at front, 66½ inches.
Crown sheet is 100 inches long.

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FLUE SHEET.

Thickness, ½ inch.

Number flues, 268; diameter flue holes, 2 inches; bridge, ¾ inch.

Flue area clear of corrugation 43½ inches high and 64½ inches wide.

Corrugation around flue area 1¾ inches deep and 2 inches wide, which has become irregular on account of flue sheet stretching due to flue expanding.

Variations indicated on figures 1 and 2 cracks in flue sheet.

Three bottom flue holes have been sunflowered; 22 cracks ½ inch to 2½ inches long vertical to the corrugations have developed below the flues, six of which have been plugged.

They have inserted a wedge-shaped patch or support 10 inches long to flue sheet, which fits into corrugation on fire side, which is held by two studs presumably to protect the cracks from the heat and the wedge to prevent the corrugation from closing together. A patch from 10 inches wide has been applied below this wedge extending to the mud ring. This flue sheet has acted very badly. In addition to developing cracks it has started to corrugate in the opposite from the original and they are nearly as large, 1½ inches high, as shown on sectional figures 1 and 2 of the sketch.

Side and crown sheets—in one piece has 21 corrugations 5½ between centers of stay bolts. In same stay bolts vertically are 4¼-inch centers.

Crown sheet has two plugged cracks.

Right side has developed 107 cracks, 28 plugged.

Left side has developed 95 cracks, 21 plugged.

These cracks are all horizontal from the edge of the stay-bolt holes. There is only one vertical crack. It is 3 inches long, and between the stay-bolts in one of the short vertical corrugations. There are no other vertical cracks in these corrugations, which suggests that the box is flexible fore and aft; that is, the short way, about 8½ inches, and inflexible the long way about 18 feet.

I have not made inspection of the Wood's box located on the New York Central and do not believe I will have an opportunity to do so as it will be necessary for me to attend a meeting in Chicago on Friday, the 13th, with Mr. Wilson and Mr. O'Brien.

Yours, very truly,

JOHN PURCELL.

JULY 24, 1913.

MEMORANDUM—REPORT, MADE FROM FILE ON WOOD CORRUGATED LOCOMOTIVE FIRE BOX, APPLIED TO ENGINE 20.

Special Requisition 524 was placed in August, 1909, for this fire box, at which time, on account of some misunderstanding, we had no formal quotation as to the cost of same, and as a result at the time bill for $2,975 was rendered, same was criticized; however, being unable to check the price, bill was paid. Also the fire box was made from Worth Brothers' steel, instead of our standard—Otis steel. Fire box was ordered equipped with O'Connor fire door.

This fire box was applied to engine No. 20, which went into service on the third district, Nebraska division, April 14, 1910.

May 24, 1910: Mr. Niland advised fire box has 30 to 40 crown bolts leaking slightly in center over arch. Also stay bolts to side sheets are leaking slightly. Flues are holding well in sheet.

June 8, 1910: Mr. Hempel advises, find that the stay bolts and crown stays are leaking badly.

June 24, 1910: Mr. Niland advises all the crown bolts are leaking very badly every trip and will only hold by calking. Stay bolts to side sheets are leaking in fire line. Flues are holding good; no cracks.

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June 30, 1910: Button head crown stays are leaking very badly, and it will be necessary to hold engine in the shop in the near future and drill off button heads and rivet the bolts over as calking seems to do but very little good. Mr. Hempel makes recommendation that the stay bolts should be in the concave side of the corrugation instead of the convex side of the corrugation. States so far the flues have given no trouble and no cracks have developed in any part of the box.

July 28, 1910: Mr. Niland advises the crown bolts are leaking badly every trip and stay bolts to side sheets in fire line are leaking. No signs of any cracks starting as yet. Flues are holding out good.

August 9, 1910: Mr. Hempel advises the stay bolts and crown stays leak very badly and must be continually worked upon as they loosen up nearly every trip. Mr. Hempel would suggest that engine be held in and that all bolts be redriven and that engine be changed to run either between Cheyenne and Sidney or between Cheyenne and Laramie, where water conditions are different.

August 18, 1910: Mr. Niland states can not bring engine 20 to fourth district as can not use her in place of Pacific type engine and have no Pacific type engine to put in her place. States Mr. Beery advises engine is being held at North Platte and repairs are being made to crown bolts. The crown bar bolts merely drop water; they never run in a stream and never seem to cause any trouble.

August 25, 1910: Mr. Niland advises fire box is in good condition and no signs of any cracks. Flues are holding well. Engine is being held for crown bolts and new ash pan. Crown bolts have been leaking badly every trip. Stay bolts to side sheets in fire line are also leaking.

September 27, 1910: Mr. Niland advises fire box in good condition and crown bolts holding better as we chipped and calked all bolts. Stay bolts to side sheets are leaking in fire line under arch.

October 17, 1910: Mr. Hempel states fire box has given considerable trouble with stay bolts and crown stays leaking. It has been necessary to go over engine and redrive them all. Flues up to present time have not given much trouble; however, they leaked some. Fire box at the present time has developed no cracks, only trouble being the leaking of crown stays and stay bolts.

October 26, 1910: Mr. Niland advises fire box is in good condition and as yet no cracks have showed up. Crown bolts and stay bolts are giving us great amount of trouble on account of leaking. Have hammered same up, but they will not stay tight.

November 15, 1910: Mr. Niland forwards inspection report of Boiler Maker Foreman Chapman. Fire box sheets are good, no cracks showing. Stay bolts all leaking quite bad. Button head stays (of which there are six rows) have been calked and trimmed off until they assume the shape of ⅞ cone-head rivet and are still leaking. The radial driven stays in crown, each side of button heads, are all leaking. There is not a tight stay bolt or button head stay in the fire box. Mr. Niland states they are going to apply 120 button head stays and hammer up all stay bolts, also put in new driving axle.

November 23, 1910: Mr. Hempel states it is necessary to renew all button head crown stays. It will also be necessary to redrive all stay bolts on the fire side. No cracks have developed in fire box.

November 28, 1910: Superintendent at Cheyenne advises fire box in good condition; has no cracks; as yet flues are holding out well.

January 24, 1911: Superintendent at Cheyenne advises fire box has started to crack. Has ⅛-inch crack in corner of door-hole flange and another crack 1½ inches. Stay bolts to side sheets are leaking, nearly every trip and crown bar bolts are leaking, but flues are holding good. No crack as yet to side and crown sheets. Flue sheet good.

February 17, 1911: Mr. Hempel advises the O'Connor fire door has eight small cracks from 1 to 1½ inches long, also one crack, as shown on sketch, 12 inches long.

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PHOTOGRAPH No. 1.—Fireside back flue sheet.

Showing cracks in lower flange of corrugation. Circles represent plugged cracks; straight lines, cracks not plugged. Bottom flue holes in third, eleventh, and twenty-first rows are sunflowered on account of cracking through top flange of corrugation. Top patch is wedge shaped where it enters the corrugation, and seems intended to protect from the fire small cracks in the bottom of corrugation and prevent the corrugation from closing together.

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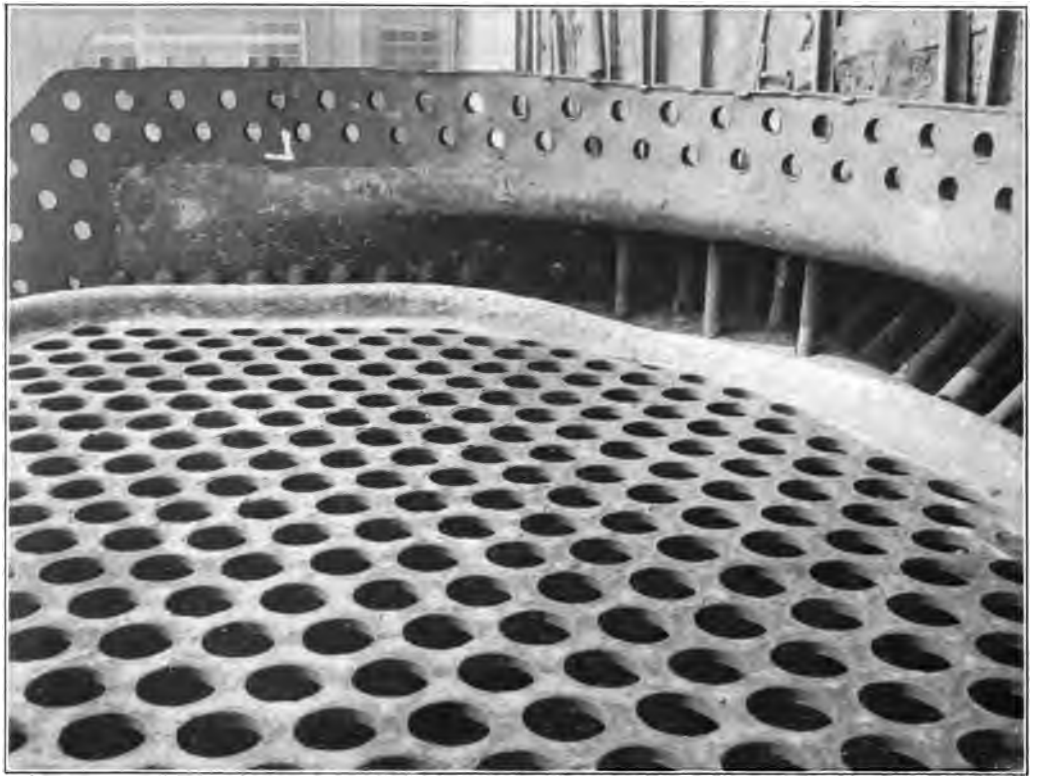
PHOTOGRAPH No. 2.—Left half of back flue sheet. Water side.



Shows reduction in depth of the side corrugation on account of bulging on fireside below the corrugation, while near the center the corrugation has enlarged to the water side, which is probably the reason for applying wedge-shaped block or patch shown in photograph No. 1.

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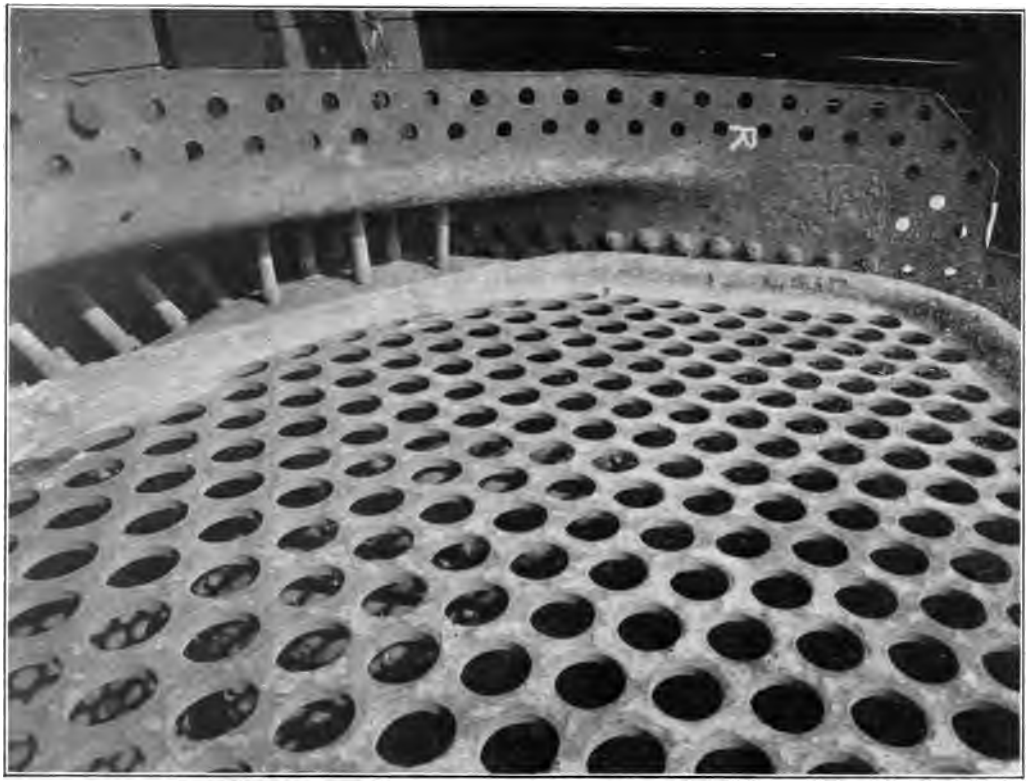
PHOTOGRAPH No. 3.—Right half back flue sheet.



Very similar to left half of sheet shown in photograph No. 2.

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PHOTOGRAPH No. 4.—Showing full view water side back flue sheet area and corrugation.

Bottom flue holes third, eleventh, and twenty-first rows sunflowered on account of cracking into upper flange of corrugation, also showing plugs applied in bottom of corrugation at center on account of cracking. Top corrugation shows many incipient cracks, and some well defined running lengthwise with the corrugation. These are nearly through the plate.

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PHOTOGRAPH No. 5.

Showing top center of flue sheet water side and deterioration in corrugation due to crimping movement of corrugation while under stress of working pressure. Considerable corrosion may also be detected at the upper part.

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PHOTOGRAPH No. 6.—Showing crown sheet staying.

Each stay is applied in a corrugation that projects 1½ inches into the fire 4½-inch centers. The close arrangement suggests extreme difficulty in keeping this part of the boiler clean, particularly crown sheet.

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PHOTOGRAPH NO. 7.—A little to right of center, looking slightly downward.

At flue sheet connected to crown sheet showing slight corrosion at rivet seam, hard incrustation in hollow of crown sheet, corrugation showing the center stays working loose in sheet and slight corrosion of sheet where bolt penetrates it at the bottom of the corrugation, which is 1½ inches deep where bolts are applied.

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PHOTOGRAPH No. 8.—Showing cracks in fire-box sheets.

Circle marks represent plugged cracks, straight lines unplugged cracks. Flue sheet, 22 cracks ½ inch to 2½ inches long, 7 of which are plugged. Three flue holes sunflowered. Left side has 95 cracks, 21 of which are plugged. Right side has 107 cracks, 28 plugged. Crown, 2 plugged cracks. All cracks in corrugations but one are horizontal. One 4-inch crack plugged in lower part of door sheet.

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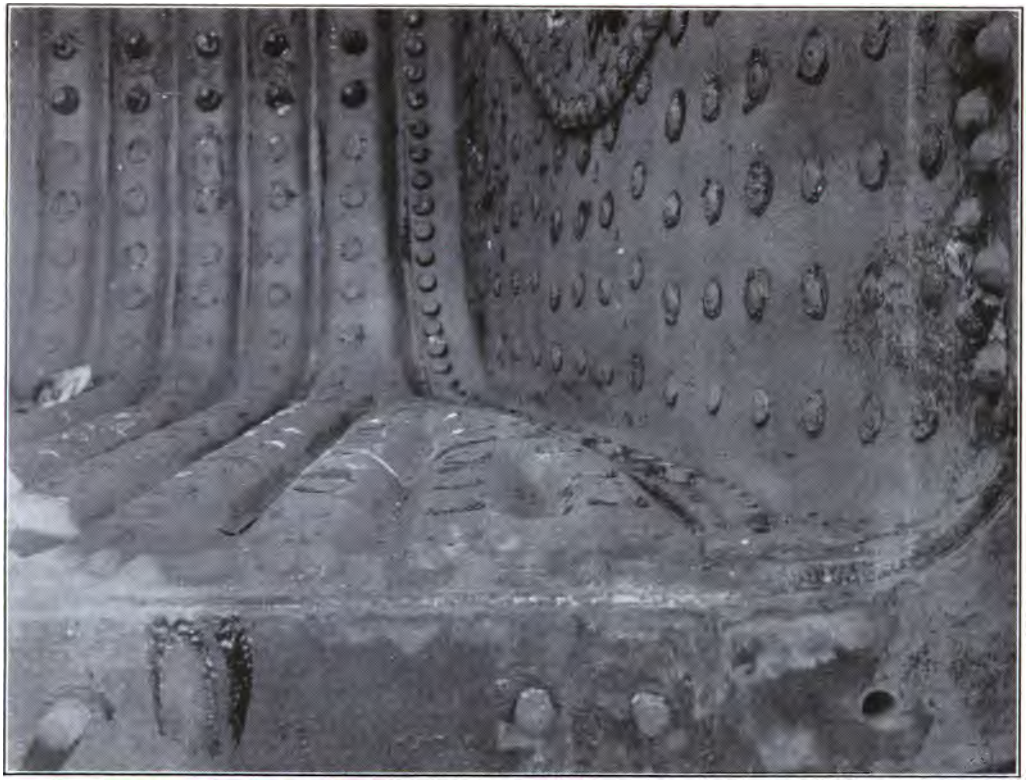
PHOTOGRAPH No. 9.—Showing back area of right-side sheet.



Note distortion of plate above corrugated depressions. This close up gives an idea how hard the stay bolts have been worked, wnich is not surprising considering the extreme difficulty of keeping fire boxes of this type clean.

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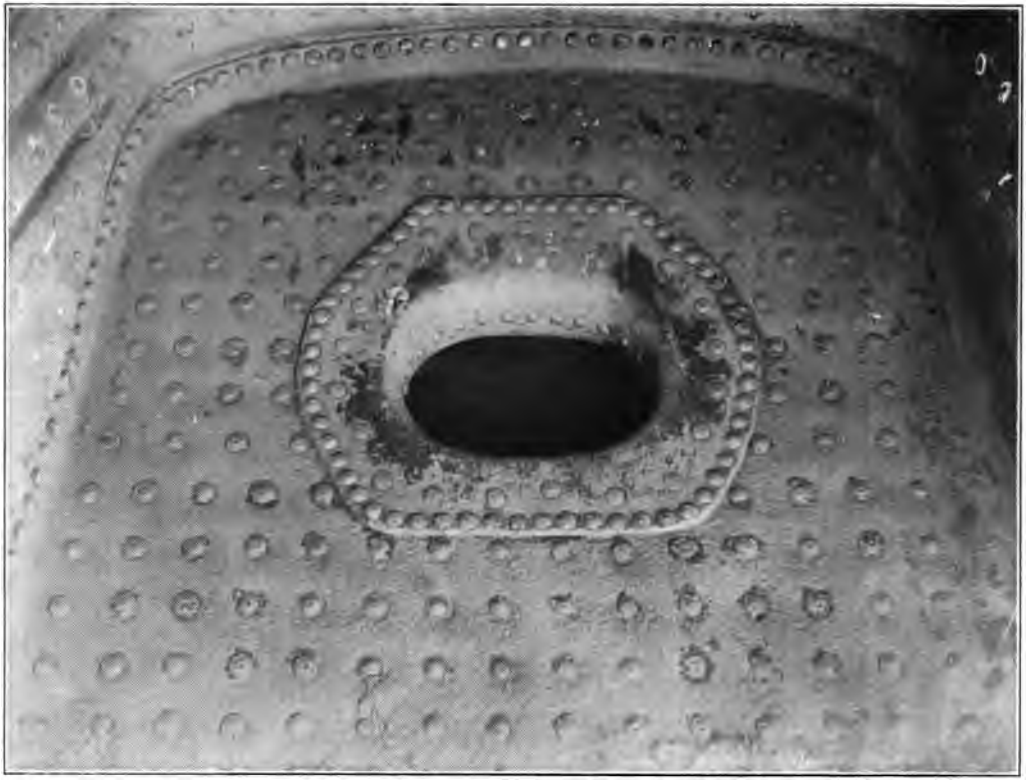
PHOTOGRAPH NO. 10.—Door sheet.



Showing patch around fire hole; also shows a 4-inch crack plugged at the lower part near the center. This originally was an O'Connor fire door flange. On the left of the photograph, near the rivet seam, is shown by a straight line the only vertical crack in this fire box; that is, in the corrugations.

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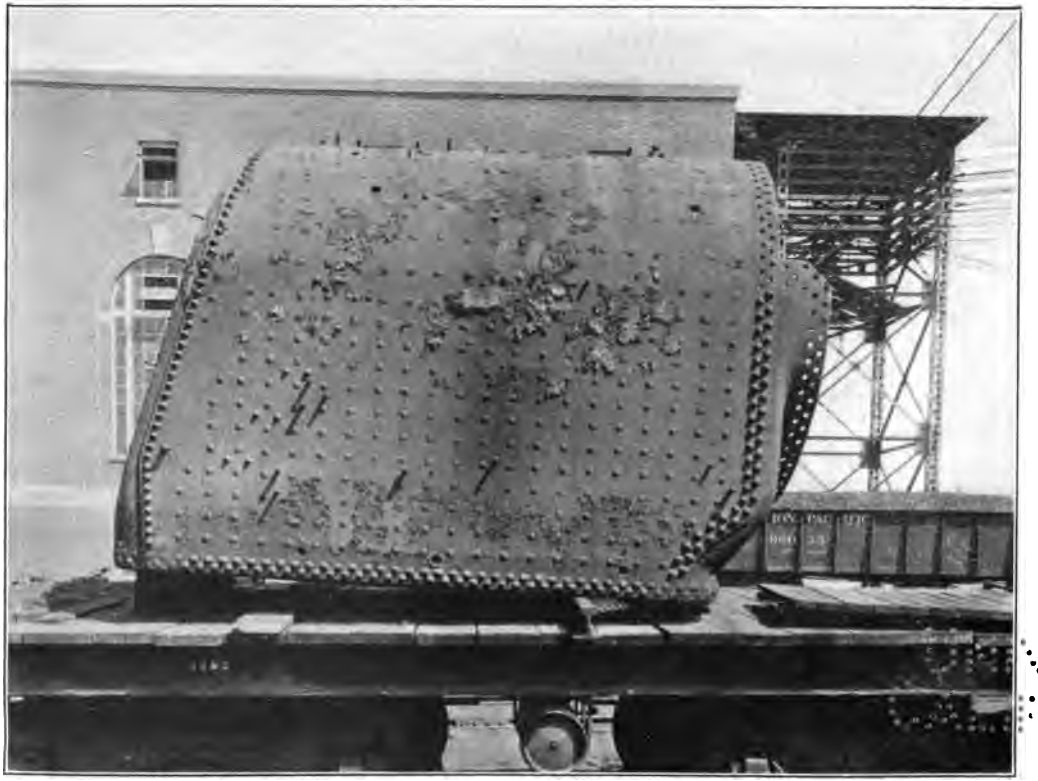
PHOTOGRAPH NO. 11.



Showing location of washout plug holes in fire-box casing for corrugated fire box. It is the general practice to have more holes in standard box than is shown in this case.

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Will have to hold engine to apply a new door collar. Crack in bottom knuckle of flange and, on account of particular corrugation of sheet, very difficult to apply patch. However, at present, crack is not sufficient length to require plugging; also one small crack, about ½ inch long, in left side sheet. Stay bolts and crown stays are leaking; have been ever since she has been in service.

February 24, 1911: Superintendent at Cheyenne advises fire box has a 2-inch crack in back flue sheet to knuckle of flange below flues; has nine cracks 1½ inches long and one 8-inch crack plugged to door hole. Stay bolts and radial stays leak every trip. Some small cracks have started from stay bolts to side sheets in fire line. Flue hold well, but fire box does not hold out very well.

March 24, 1911: Superintendent at Cheyenne advises fire box has 13 cracks 2 inches long and one crack 8 inches long plugged to door hole. Three cracks to back flue sheet 2½ inches long to knuckle of flange and three small cracks ½ inch long to side sheets. Stay bolts and radial stays leak nearly every trip. Flues are pitted and bursted. Engine is in shop for new flues and patches.

March 31, 1911: Mr. Hempel states the O'Connor fire door was applied to engine 20, which is equipped with Wood's corrugated fire box, having been in service 11 months. This fire door has 17 cracks from ¾ to 1 inch long and one crack 8 inches long. This fire door is being cut out and will be shipped to Omaha for your personal inspection should you desire to see same.

May 24, 1911: Engine 20 has door collar to door hole and four cracks to flue sheets below flues 1½ inches long plugged. Side sheets, crown sheet, and crown-bar bolts are in good condition. This from superintendent at Cheyenne.

June 27, 1911: Superintendent at Cheyenne advises stay bolts and crown bolts are leaking bad every trip. States they will not hold in sheet; has four cracks to back flue sheet 2 inches long below flues. Flues are holding well. It is their opinion that the expansion and contraction in fire box continually loosens the stay bolts in the side sheets.

May 1, 1912: Mr. Vickroy writes reporting in main as above of March 1, recommending that the engine be given a new fire box.

May 10, 1912: Mr. Fuller writes superintendent at Denver, "Have instructed Mr. Hatz to ship back end for engine 20 to Denver." Requested that back end removed from engine 20 be sent to Omaha.

July 26, 1912: Wood's back end shipped to Omaha.

August 27, 1912: Mr. Hatz advises Mr. Fuller inspected the Wood's fire box from engine 20, and issued verbal instructions to store fire box at Omaha shop so that it can be inspected by anyone at any future time.

August 13, 1913: We advised Mr. William H. Wood that their fire box was applied to one of our engines in April, 1910, and was removed from service May 1, 1912, on account of fire box failing, due to cracks in side sheets, flue sheets, and door sheets. During the time this engine was in service it was almost an impossibility to keep radial stays and stay bolts tight in the sheets.

July 25, 1911: Superintendent at Cheyenne advises fire box has six cracks started to side sheets in fire line under arch 1 inch long out of stay bolts. Also has five 2-inch cracks to back flue sheet plugged below flues. Stay bolts are leaking at side sheets. Flues are holding well.

September 27, 1911: Superintendent at Cheyenne advises stay bolts and crown bolts are leaking very badly each trip. Engine has 16 cracks to side sheets in fire line out of stay bolts 1 to 2 inches long not plugged, eight cracks to flue sheet 5 to 4 inches long, five cracks plugged and a patch to door hole. Fire box is getting in very poor condition. Can not keep stay bolts and crown bolts tight.

October 26, 1911: Superintendent at Cheyenne advises fire box is in bad shape, having 25 cracks from 1½ to 3 inches long plugged to flue sheet; 35 cracks, ½ inch

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long, some plugged to right side sheet; 23 cracks, 1½ inches long to left sheet, some plugged. Can not keep stay bolts and crown bolts tight; they leak badly each trip. Had a door collar applied to door hole.

November 3, 1911: Engine No. 20 left North Platte on No. 51 night of the 2d for Denver to be put in service on Northern district, Cheyenne to Denver.

November 7, 1911: Superintendent at Denver advises engine No. 20 arrived Denver Saturday morning. Fire box has 25 small cracks on the right side sheet and 27 on the left side sheet. Cracks extend out from stay bolts and are from ¼ to ½ inch in length. On the back flue sheet there is a crack from bottom flue hole to point just above the mud ring, and was plugged on arrival here.

January 5, 1912: Superintendent at Denver advises had a great deal of trouble with fire box after arrival of engine No. 20 on account of leaks, due to several cracks. Did considerable plugging, and engine is now rendering first-class service, working in good water district.

January 27, 1912: Superintendent at Denver advises engine No. 20 rendering good service.

March 28, 1912: Superintendent at Denver advises that in applying patch to crack that extended from the bottom flue to the mud ring on the back flue sheet they experienced trouble, as they could not fit the patch to the recess that encircles the flues on the back flue sheet. States are having trouble with stay bolts continually leaking in fire box. Every trip have to calk and hammer up stay bolts and frequently tap them out and apply new stay bolts.

CHICAGO AND NORTH WESTERN RAILWAY CO.,
Chicago, September 4, 1918.

Mr. FRANK MCMANAMY,
Manager, Locomotive Section,
United States Railroad Administration,
Interstate Commerce Building,
Washington, D. C.

DEAR SIR: Referring to our discussion regarding the Wood fire box and the request that an inspection be made of the one now in storage on the Union Pacific Railroad at Omaha.

Am herewith sending you report on this by our general foreman boiler maker, Mr. T. F. Powers.

Yours, truly,

H. T. BENTLEY.

CHICAGO SHOPS, *August 31, 1918.*

Mr. H. T. BENTLEY:

On August 30 I made an inspection of Wood's fire box out of Union Pacific engine No. 20 at Union Pacific shops at Omaha. This box was applied to an Atlantic type passenger engine and was taken out of service on account of the poor condition it was in after two years' service. The box was applied and engine put in service April 14, 1910, and the back end was removed from engine on May 1, 1912.

An inspection of this fire box showed that it was badly cracked and blistered on both side sheets, and a large number of the cracks out from the stay bolt holes being plugged. There are several cracks in crown sheet and some of these plugged. All of the stay bolts showed that they had been leaking and had been very heavily calked. All the crown bolts showed they had been leaking and very near all of them had been calked.

The corrugation at bottom of the back flue sheet was cracked in several places. In fact, from the condition of this fire box it should have been taken out of service long before it was, as it must have given trouble every trip from leaking.

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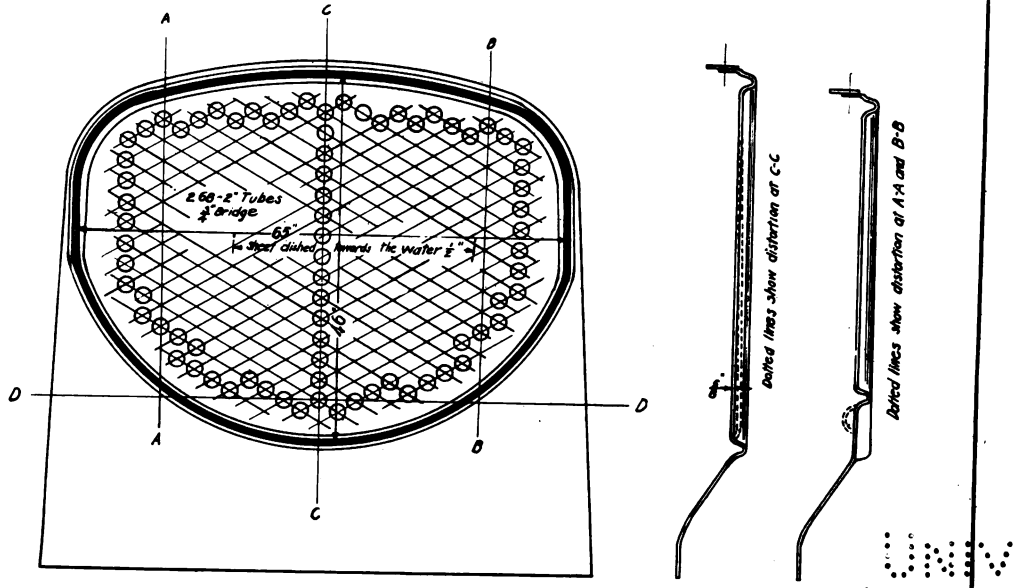

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I would not recommend this fire box to be applied to our locomotives for the following reasons:

The back-flue sheet, which is corrugated all the way around outside of the flue holes, is corrugated very abruptly and deep. Corrugation cracks due to expansion and contraction are practically impossible to repair on account of the narrowness and deepness of the corrugation. It is impossible to fit a patch into groove of corrugation, and it is impossible to plug same and make it tight; it also would be impractical to weld it because an operator would be unable to get torch to flow the metal into the groove. In fact, when this sheet cracked around the corrugation the only proper way to make repairs on it would be to renew sheet.

My next reason is that the crown sheet is corrugated, which is impractical from a maintenance standpoint. From the inside, or water side, the bolts are down in the valley of the corrugation, making a very bad mud pocket between every stay bolt, making it impossible to wash the mud and scale out.

The next reason is because the stay bolts and radial stays in side sheets and crown sheet from the fire-box side are on top of the hill of the corrugation, making it impossible to keep stay bolts tight, due to the fact that they are exposed to extreme heat of the flames in the fire box and are subject to much more severe expansion and contraction than if they were in the depressed part of the corrugation.

My next reason, if at any time it was necessary to renew side sheets on this fire box it is almost impossible to do so on account of being very hard to fit, as the corrugation in the new side sheet must correspond with the corrugation in the crown sheet, and if the side sheets had to be riveted in it would be almost impossible to make a job of them. The abrupt corrugation of the flue sheet, especially at the top, makes it very easy to be attacked by corrosion and pitting, there being considerable of this at the top of the flue sheet of this engine.

I was talking to Mr. Hempel, general boiler inspector of the Union Pacific, and he informed me that this engine began to give trouble a few months after it had been put in service. The engine was running from April 14, 1910, to November, 1911, in what is known as the third district of the Union Pacific Railroad; this being a bad water district, making a total of 19 months for the engine in that district. The corresponding service of an engine equipped with a standard fire box in this district would be between 40 and 48 months before shopping. After November, 1911, the engine was sent to the Colorado district, which is a good water district, but gave trouble continually on account of leaking, and finally was removed from service in May, 1912.

One particular reason why this box should not be applied is that I believe that it would burn much more coal than an engine equipped with a standard fire box, due to the fact that it is impossible to properly wash crown sheet, also that an engine that continually leaks like this one burns much more coal than one that can be kept tight.

I sincerely hope that you will not consider applying this type of fire box to our locomotives.

T. F. POWERS.

ATLANTIC COAST LINE RAILROAD COMPANY,
OFFICE OF GENERAL SUPERINTENDENT OF MOTIVE POWER,
Wilmington, N. C., April 10, 1918.

Mr. H. T. BENTLEY,
Mechanical Engineer, United States
Railroad Administration, Washington, D. C.

DEAR SIR: Replying to your inquiry of the 10th in regard to service from the "Wood" corrugated fire boxes:

The history of our use of the "Wood" fire box on one 10-wheel engine, and one only, is peculiar. Mr. Wood came to see me some years ago and discussed the merits of his box, and asked me to give him a blue print of the boilers of one of our standard

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engines. This request was complied with. Without authority, and without my knowledge, he manufactured a fire box, sent it to Atlantic City, and exhibited it as "Atlantic Coast Line Wood's Fire Box." The impression created on the minds of some, but without foundation, was that it had been adopted by this line as a standard.

For a number of years importuned by Mr. Wood to buy this box, and consistently refused, I finally agreed to have it applied on one of the lot of 10-wheel engines coming through the Baldwin Locomotive Works. This was our engine 1019, which went into service in September, 1912.

No unfavorable reports were received from the service of this fire box, nor were there any stay bolts renewed until April, 1915, when I received the following report:

"Fire door is cracked top and bottom; both cracks 3 inches long; also a crack in crown sheet extending 1½ inches each side of radial stay; and six radial stays leaking slightly; flues have been giving some trouble."

The following report was received September 1, 1915:

"This engine is now in South Rocky Mount for repairs and I am inclosing you sketch showing where fire-door hole is cracked at the top and bottom; also one crack about 1½ inches long on each side of one of the radial stays in the left side of fire box; two small cracks, one on each side of two other radial stays in the same locality. On examining fire box from the interior of the boiler, crown sheet was found to be practically free from any accumulation of mud. There was found, however, a small amount of scale that had accumulated on the sheet around the stays. This small accumulation of scale was no more than one would naturally expect to find on any other crown sheet."

In November, 1915, the crown sheet of this box was slightly damaged, presumably by low water, as indicated by the report of the district Federal inspector addressed to the chief inspector, Mr. McManamy, and dated November 25, 1915. Our local representatives, however, do not altogether agree with the conclusion reached by the Federal inspector, as is evidenced by the following quotation from the letter of our superintendent of motive power, Mr. Sprowl, dated December 21, 1915:

"You will recall that this is the engine that 165 crown bolts were found leaking at Florence. After bringing engine to South Rocky Mount shop for repairs we found 11 cracks in the crown sheet of this engine, extending anywhere from ½ to 1½ inches from the radial stays. We removed these bolts, welded the cracks, and after applying hydrostatic test five more cracks were discovered, making a total of 16 cracks in all.

"I am of the opinion that the corrugated crown sheet is responsible for the cracks in the sheet of this engine, from the radial stays and crown bolts in the fire box, and do not believe that we will get satisfactory service out of this crown sheet, and same will give us continuous trouble until same is removed, and I feel that this will only be a short time. I think we should look into the changing of this fire box with a view of removing the corrugated box and putting a standard box in this engine.

"After examining these crown bolts at South Rocky Mount, I feel satisfied that the damage to this engine was not caused by low water. The expansion and contraction in the corrugated crown sheet is what is cracking the side sheets and crown sheets from the holes where the radial stays and crown bolts are applied. On examining the crown sheet from the interior of the boiler before removing the crown stays, we found a small accumulation of mud around several of the stays. This mud was in the shape of a small cone, about 2 inches in diameter and 1½ inches high, this accumulation of mud around the bolts no doubt being due to the bolt leaking, as this would cause the mud to gather around the bolt.

"I am attaching Boiler Form 1, which shows the location of the bolts removed and number and location of the cracks.

"You will note that 13 of the 15 cracks are at the radial bolt holes in the same locality that we found the three cracks when this engine was repaired at South Rocky Mount shop in August."

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You will note from the following extract from my reply to Mr. Sprowl, dated December 24, 1915, that we are not altogether agreed as to the cause of the damage to the crown sheet in November, 1915.

"I have your letter of the 21st in reference to partial failure of the Wood's corrugated fire box. I hope that by welding up the cracks you will be able to extend the life of this fire box a considerable period. You understand the only difference in this fire box and that of other engines in the same lot is in the Wood's corrugated features and smaller number of tubes. When necessary to replace it, a new box may be ordered on Waycross shops. You should be careful to specify, in ordering, the number of flues and their location to correspond with front flue sheet. Full information can be had on this box by application to the mechanical engineer.

"I am inclined to believe that the cracks in this crown sheet, radiating from the crown stays near the shoulder of the fire box, that is where the fire box has the smallest radius, joining the side sheets and crown sheets, are due to the accumulation of mud around the base of the radial stays, and that the accumulation of mud is due to the fact that the radial stays, passing through the bottom of the corrugation, forms a dam or obstruction to the circulation of the water, carrying mud and other solid material which collects around the radial stays. The cone shape accumulation seems to bear out this theory, as the diameter of the cone is greatest where the circulation of the water is slowest; that is, at bottom of the corrugation, and the diameter is smallest where circulation is most rapid. I do not believe, as suggested by you, that the accumulation of mud is due to leakage of the stay bolts."

On March 7, 1916, the following report was made:

"I beg to advise this fire box is still in service on engine 1019. The crown bolts are still leaking but giving no trouble."

On April 5, 1916, the following report was made:

"I beg to advise that the crown bolts are not leaking now on engine 1019, but there is a crack in the top of the fire door 4 inches long, and one in the bottom of the fire door 4 inches long. Both of those cracks are continually leaking. Two superheater flues are broken at welds and leaking."

On June 28, 1916, the following report was made:

"The crown bolts and flues are not leaking in the fire box of engine 1019, but the cracks in the top and bottom of fire door are continually leaking."

On August 17, 1916, the following report:

"We have patched the top and bottom of the fire door; and crown bolts, flues, and fire door are now O. K."

On December 22, 1916, the following report was made:

"This engine has what is known as the Wood corrugated fire box, and upon arrival of the engine here it was leaking so bad that it was impossible to keep the engine alive, the leaks were so numerous. We attempted to put the pressure on this boiler with cold water, and with 30 pounds' pressure about 40 or 50 little cracks showed up in different parts, and especially just above the fire line and a few up in the O. G. of the fire box that would squirt from one side of the fire box to the other. We have cut this engine out of service and sent it to Rocky Mount."

Under date of December 29, 1916, I authorized the cutting of this box out and the application of the new standard fire box.

You will note the life of this fire box was about four years, which is a very short life for this section of the country; the water and other operating conditions are such that the fire boxes last from 10 to 12 years and longer; in fact, we have some fire boxes, running in high-pressure engines that were applied to the engines when built new in 1896.

My opinion of this fire box is that, while the corrugation of the side sheets probably has some effect on the life of the stay bolts, it provides flexibility only in a horizontal

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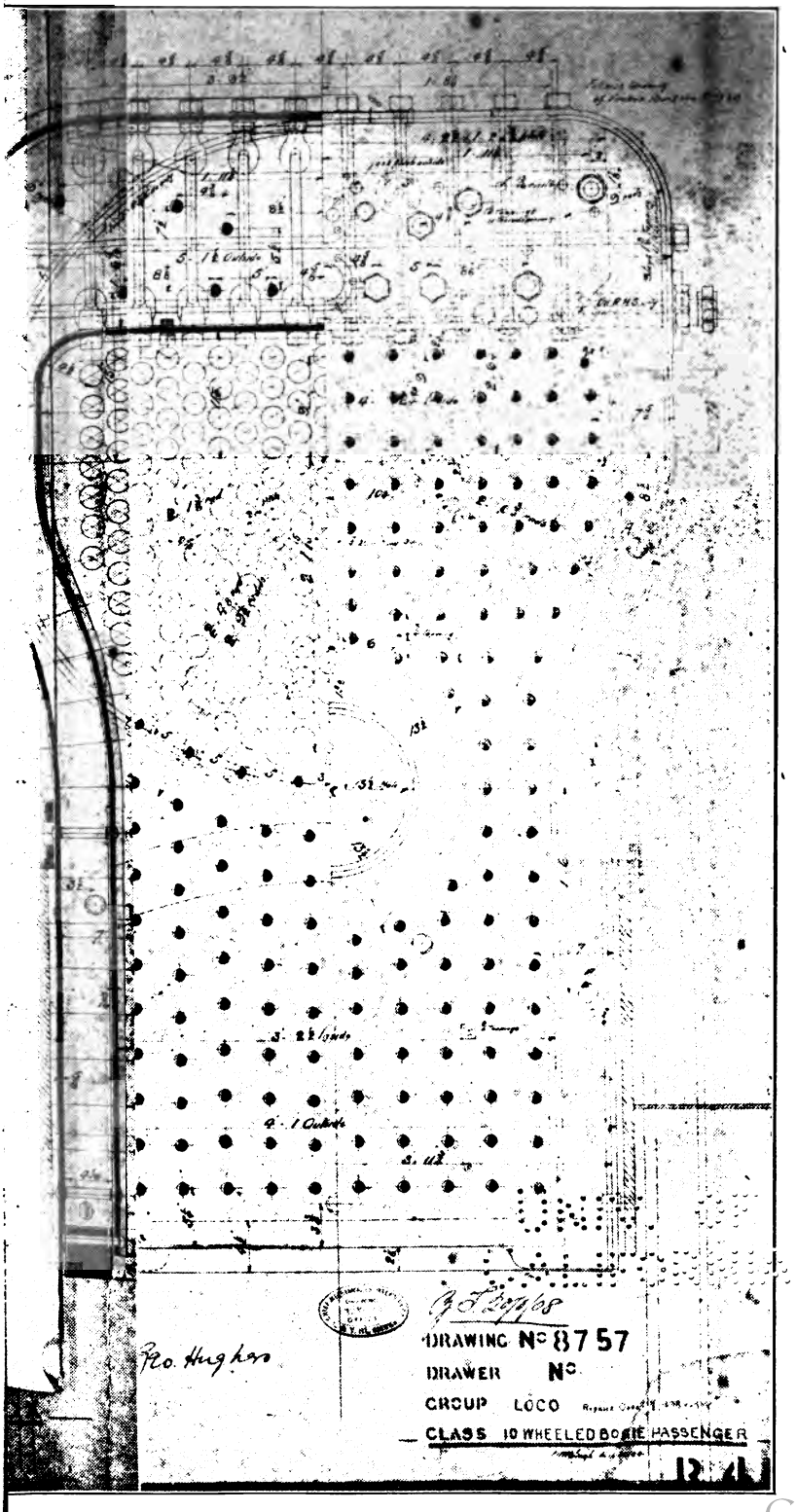

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line, and none vertically, and therefore the relief due to the corrugations is only partial.

The real defects, in my judgment, in the life of the box comes from the fact that the corrugations, instead of prolonging the life of the box, tend to reduce it, due to the knuckling effect at the bottom of the corrugations, and that cracks at that location are sure to develop earlier than would be the case with flat surfaces.

Like most other mechanical officers, I have had some interesting interviews with Mr. Wood, who is not easy to convince.

Yours, truly,

R. E. SMITH,
General Superintendent of Motive Power.

Witnesses:
J. T. WALLIS,
G. S. M. P., Pennsylvania Railroad Co., Altoona, Pa.
JOHN HOWARD,
S. M. P., New York Central Railroad,
Grand Central Terminal, New York, N. Y.

LANCASHIRE & YORKSHIRE RAILWAY,
CHIEF MECHANICAL ENGINEER'S OFFICE,
Horwich, Lancashire, England, March 20, 1908.

A. W. GIBBS, Esq.,
General Superintendent Motive Power,
Pennsylvania Railroad Co.,
Altoona, Pa., U. S. A.

DEAR MR. GIBBS: In reply to your letter of the 3d March, I have much pleasure in sending you fire box drawing 8757, which probably is the same that your friend has sent you, and in addition I send you the following drawings:

No. 10033, Belpaire fire box with back plate radiused inward.

No. 8014, Boiler with corrugated fire box.

No. 2758, Standard fire-hole door.

I may tell you that such an arrangement has been in extensive service on our road, and the only advantage which it proved was the fact that you could handle your inside fire box readily, and hydraulically rivet the back head to the junction of the shell. But our experience has been so wretched in regard to grooving and cracking that we have now abandoned this form and gone back to our old pattern, as shown in drawing 10033. I send you camera photographs of some of these cracks, and have also indicated on drawing 8757 their location, and may state that this form of deterioration extended right away round the plates in question.

As your letter also mentioned corrugations, I thought that I would be quite clear and send you a print of a boiler, of which we have 21 running, with corrugated fire boxes, generally known in your country as the Vanderbilt boiler. Here, again, our experience is such as to warrant the discontinuance of their use as they wear out, solely on the score of fuel consumption, which probably would not have so acute a comparison in your country.

The boiler maintenance at the fire box end is less than with our ordinary practice, because we have expensive material to deal with in ordinary practice, but this economy of maintenance is more than counterbalanced by the extra amount of coal consumption.

Yours, truly,

GEO. HUGHES.

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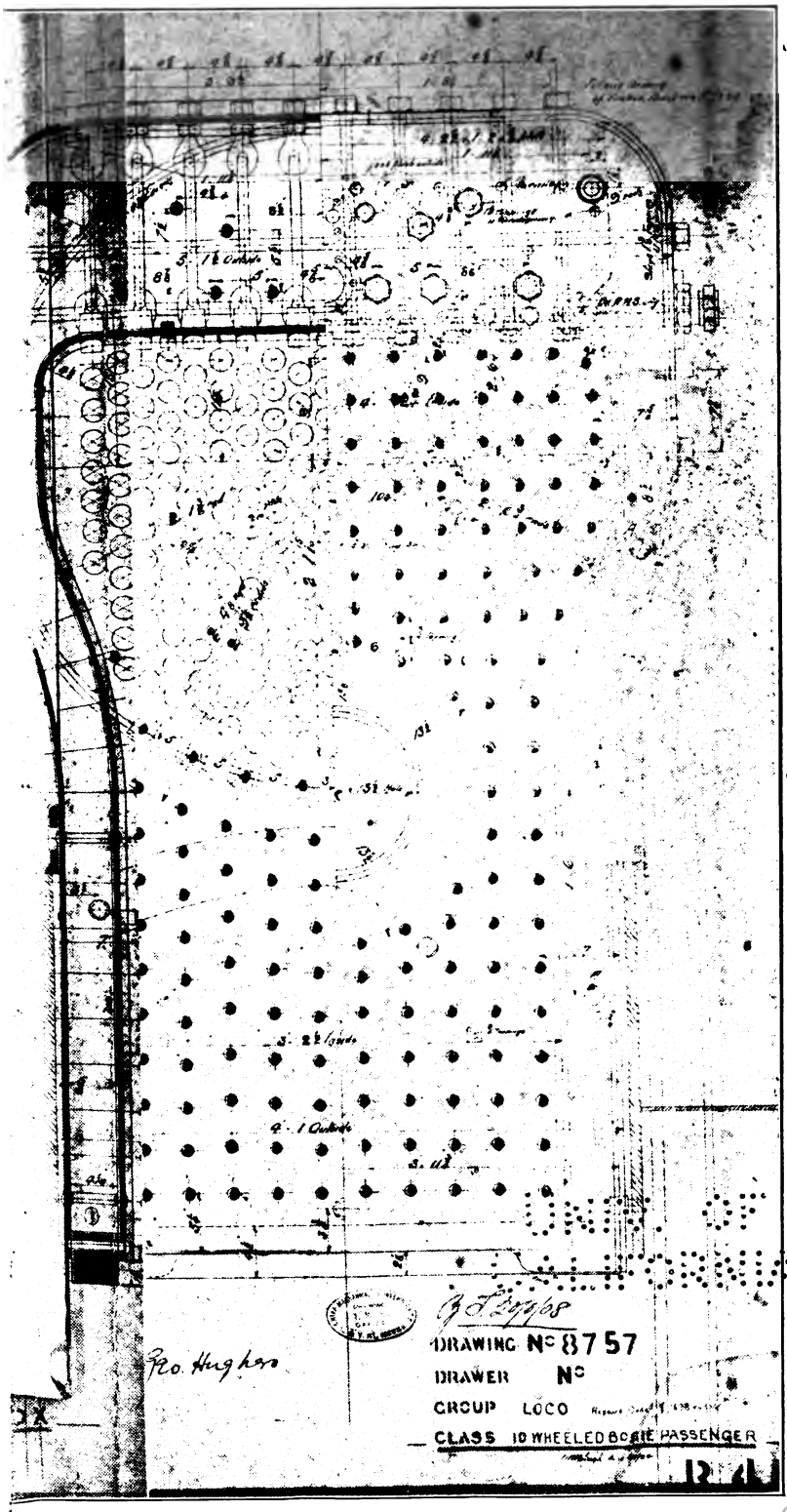

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LANCASHIRE & YORKSHIRE RAILWAY,
CHIEF MECHANICAL ENGINEER'S OFFICE,
Horwich, Lancashire, England, April 7, 1908.

A. W. GIBB, Esq.,
General Superintendent Motive Power,
Pennsylvania Railroad Co.,
Altoona, Pa., U. S. A.

DEAR SIR: Further to my letter of the 20th March, I am now in a better position to understand the full meaning of your letter of March 3.

Since writing you I have had a communication from Mr. W. Wood, builder of special machinery, Media, Delaware County, Pa., in which he incloses quite a number of blue prints applying corrugated flue sheets to American boilers, etc., and among the same there is evidently the blue print to which you referred, a full-sized photograph of which I have pleasure in inclosing, as well as a copy of the letter I received from Mr. Wood, and my reply.

You will also be interested in knowing that Malam took out a patent in this country in 1893, Specification No. 7305, for "Improvements in fire boxes," a pencil tracing of which I inclose.

In the light of this additional information I do not think I can add anything material to my letter of the 20th instant.

With kind regards,

Yours, truly,

GEO. HUGHES.

HORWICH, *March 31, 1908.*

Mr. W. H. WOOD,
Engineer, Media, Delaware County, Pa., U. S. A.

DEAR SIR: I am much obliged to you for your letter of the 18th March and interesting inclosures.

The experience I have had with steel fire boxes and corrugated flues for locomotives is such that would not warrant me in taking the matter up.

It is a somewhat curious coincidence that I should bear the same name as the gentleman you met 30 years ago. I had not the pleasure of knowing him beyond repute, and I understand that he has been dead for some years.

Yours, truly,

MEDIA, PA., *March 18, 1908.*

GEO. HUGHES, Esq.,
Lancashire & Yorkshire Ry. Co.,
Horwich, Lancashire, England.

MY DEAR SIR: I have come across a print of one of your boilers over here and have taken the liberty of having my draughtsman show in it one of my patent locomotive fire boxes and tube plates.

I know that you are interested in improvements, and will be pleased to know that I am building three of the largest consolidation boilers for the New York Central lines of this plan, the boilers of which are 80 inches diameter, $\frac{13}{16}$-inch plates, and have 458, 2-inch tubes, 16 inches long. They are about the largest locomotive boilers used in this country.

I am also building a fire box and tube plate for an Atlantic standard type of boiler for the Union Pacific Railroad Co.

The question of my getting up this fire box came about by attending the different mechanical conventions of the railroad people in this country in regard to what

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difficulties they had to contend with, and being the recognized father and builder of hydraulic riveting and flanging machinery in this country, I was asked if I could not get up something that would assist them in overcoming the difficulties they have to contend with, and this is the outcome, which has been very favorably received, possibly on account of my reputation, by a large number of engineers, and is being urged by all the railroad presidents in this country on account of the cost of repairs to fire boxes and tube plates, as at present constructed, which is a very costly affair.

I wish to inform you that I had the pleasure of being introduced to you by Mr. Richard Ackley, and at that time I had quite a talk with you in the drawing office at Miles Platting; this was some time before I left England. Your Mr. Richard Ackley was one of my father's (James Wood) apprentices, and Mr. Jenkins, the senior superintendent of motive power of your road, was a great friend of my father's, as well as his family. Possibly you might remember me, and again you might not. I left Manchester 29 years ago. I sincerely hope I may have the pleasure of meeting you again.

It will certainly be a great pleasure to have you write me a few lines as to what you think of my improvements, and I assure you my plans have the indorsements of a large number of leading engineers here.

There is no doubt in my mind steel fire boxes and tube plates made in this form can be used by you good people, same as we use them here. You certainly have no worse water conditions to contend with than there is in this country. From the knowledge I have of England, I would presume my statements would be verified.

In the meantime I wish to extend to you my very kind regards, and hoping this will find you in the best of health, I am,

Yours, very truly,

(Signed) W. H. Wood.

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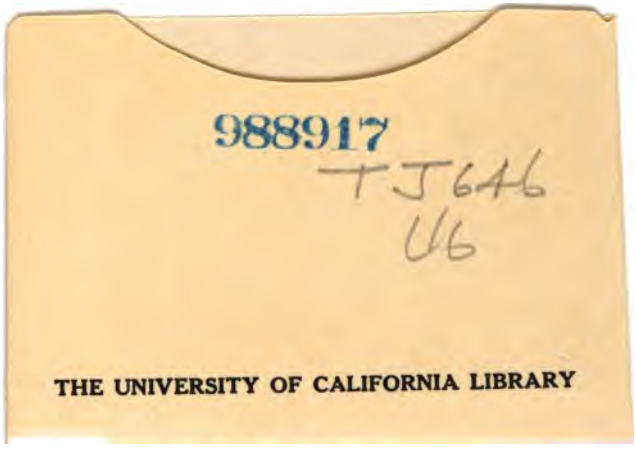
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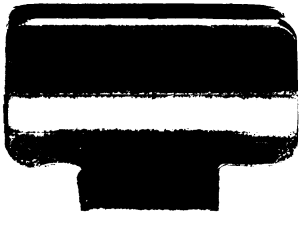

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